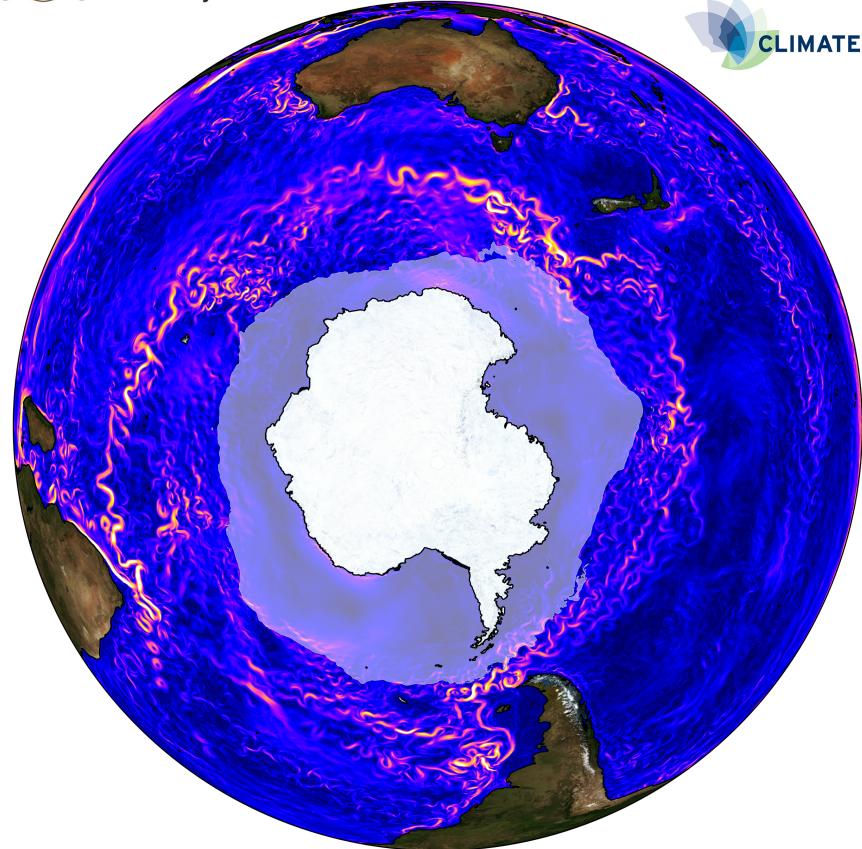


Vertical resolution of global ocean models

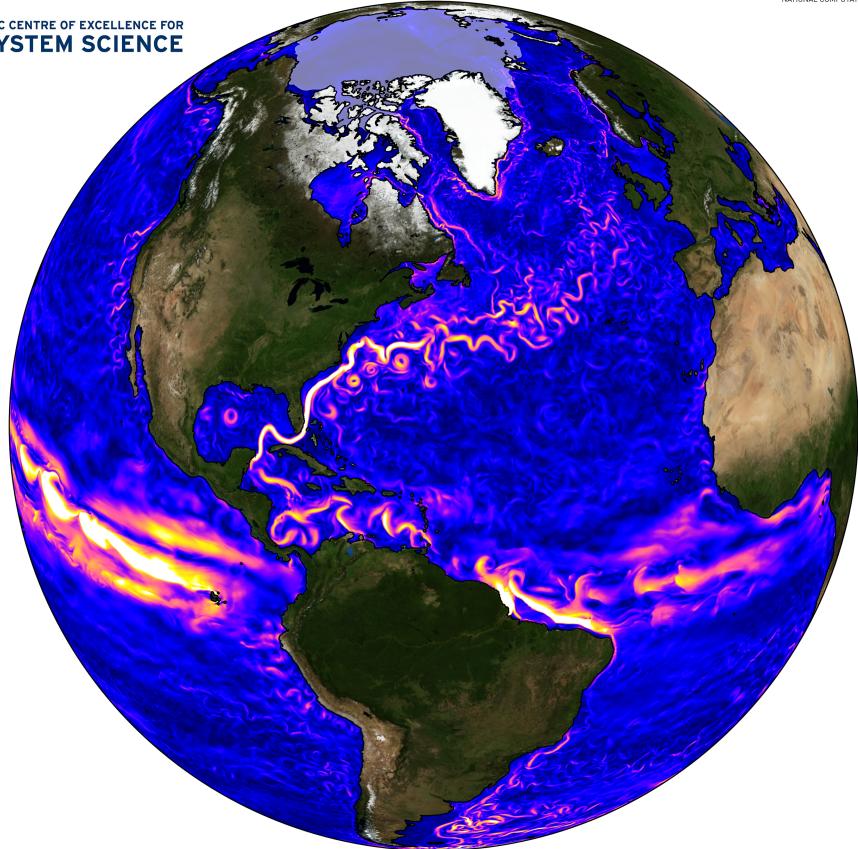


Australian
National
University

Ocean Surface Current Speed in an Eddy-Resolving Model



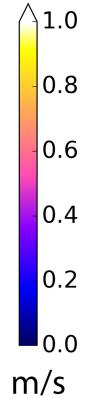
Southern Ocean



North Atlantic Ocean



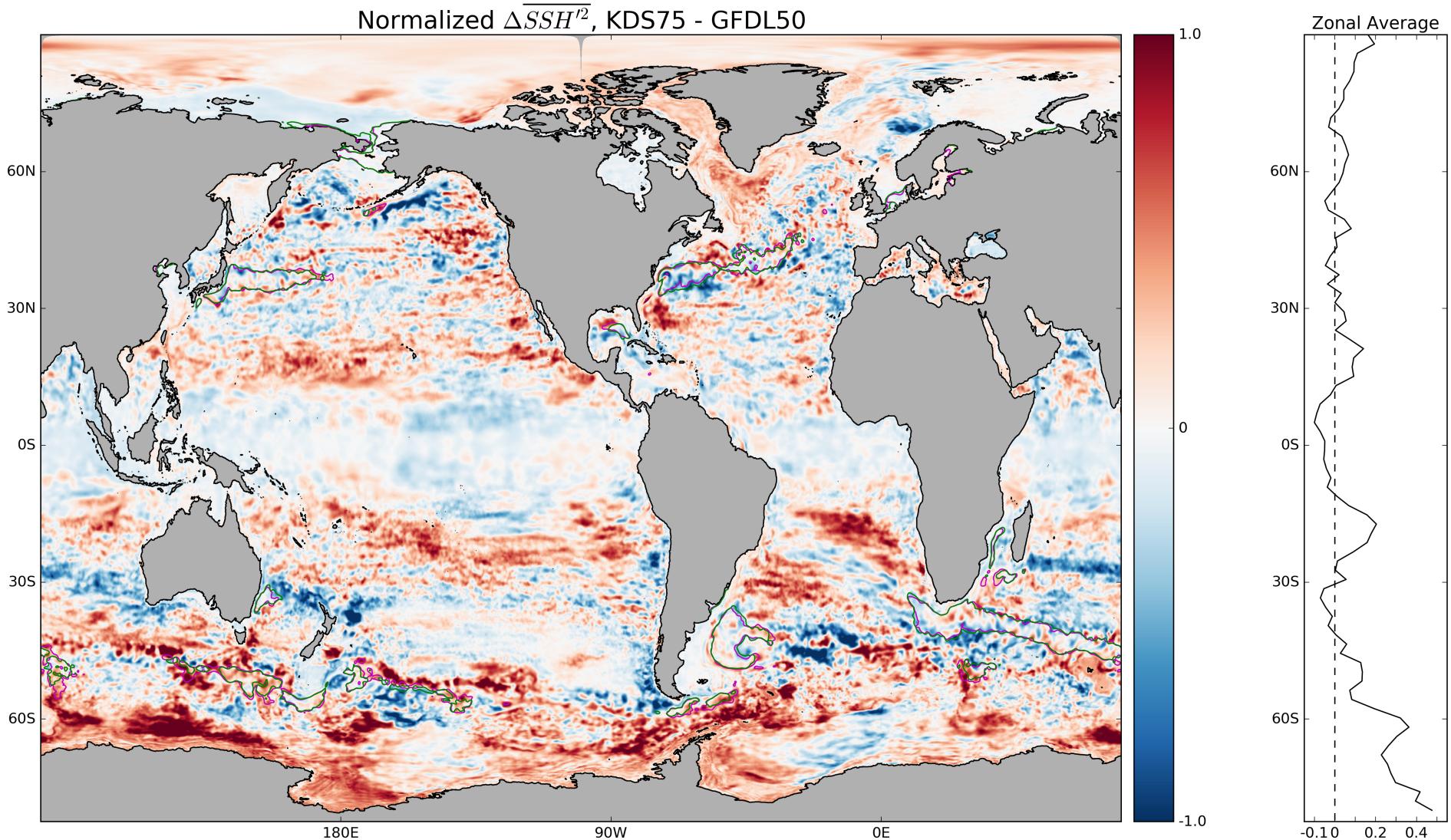
ARC CENTRE OF EXCELLENCE FOR
CLIMATE SYSTEM SCIENCE



Kial Stewart, Andy Hogg, Steve Griffies, Aidan Heerdegen,
Marshall Ward, Paul Spence & Matt England
kial.stewart@anu.edu.au

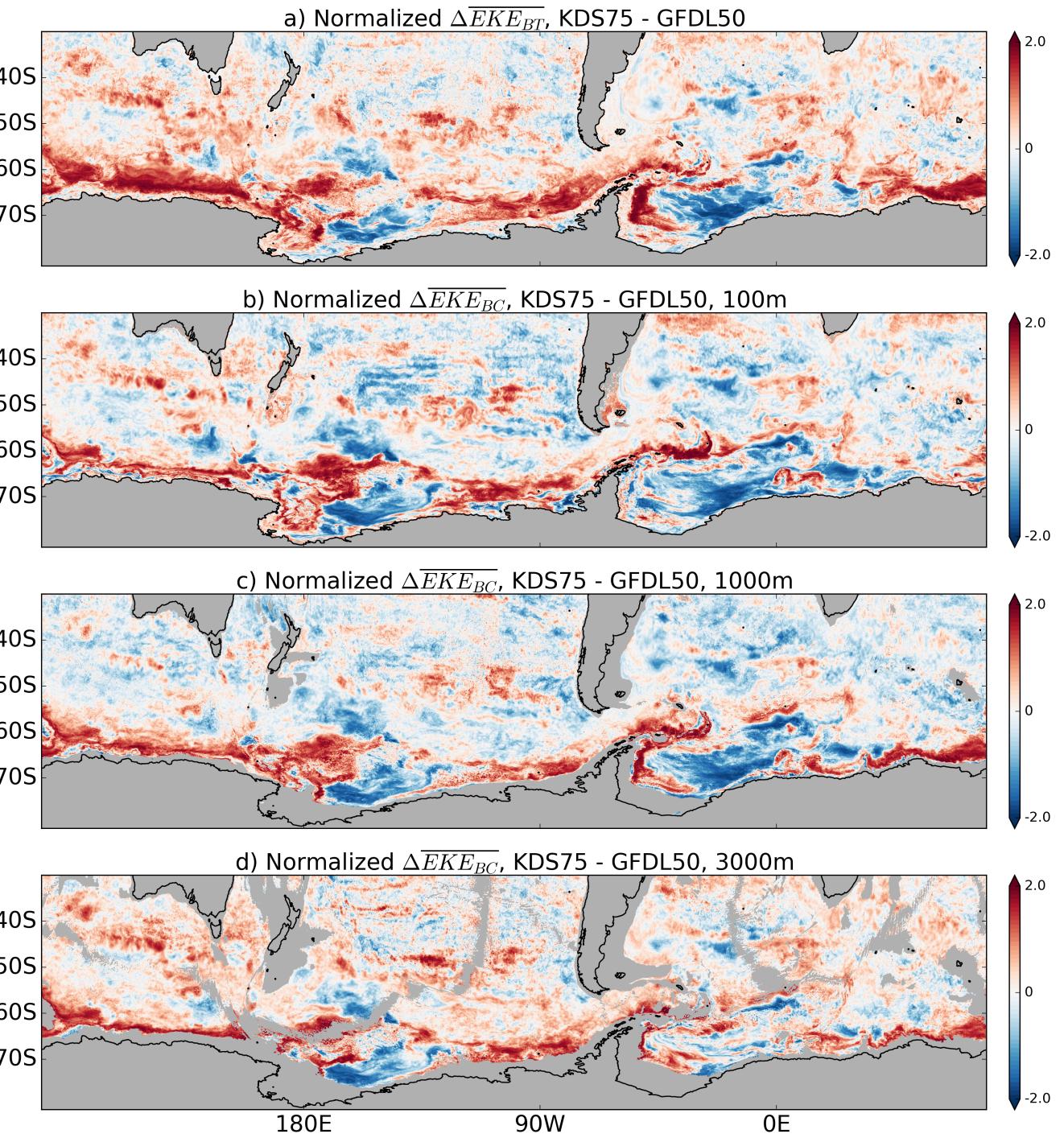
MOM5-SIS
ACCESS-OM 1/10°
www.cosima.org.au

Normalized sea surface height variability difference 75-level minus 50-level, 10-year daily



**5-year daily u,v
75-level minus 50-level**

EKE barotropic
difference



10-year mean

OVERTURNING STREAMFUNCTION
IN DENSITY SPACE: 50-LEVEL

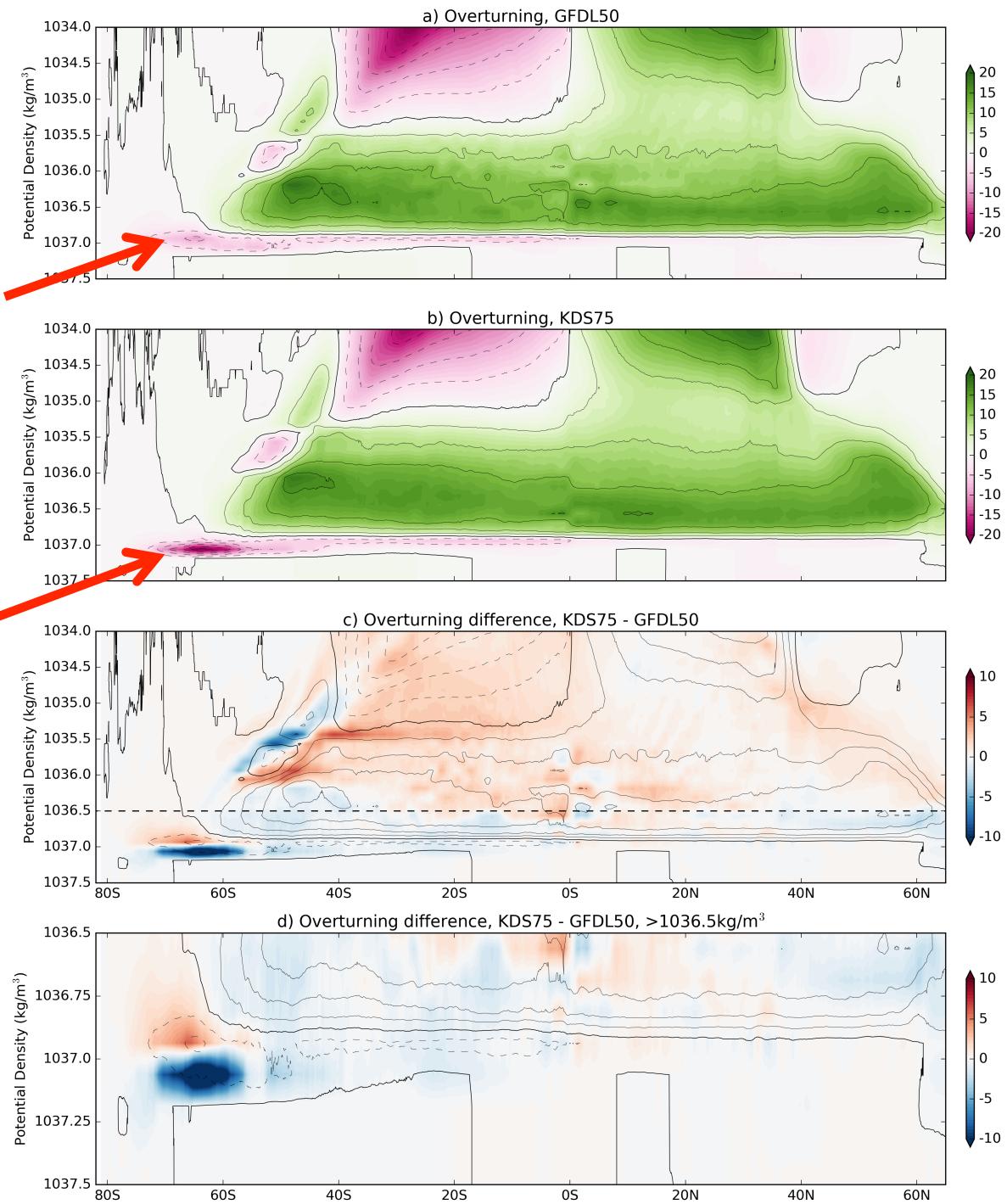
7Sv

OVERTURNING STREAMFUNCTION
IN DENSITY SPACE: 75-LEVEL

23Sv

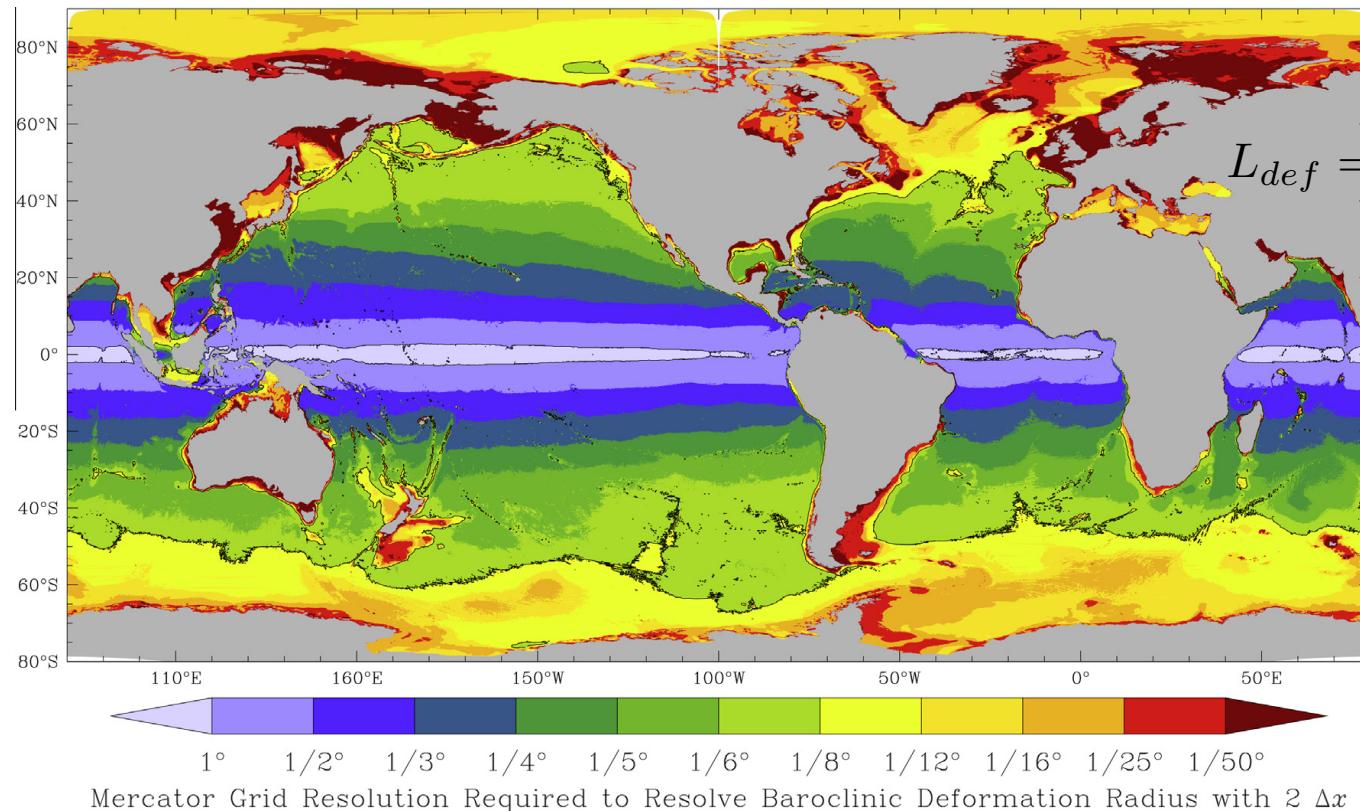
OVERTURNING STREAMFUNCTION
IN DENSITY SPACE: DIFFERENCE

75-LEVEL MINUS 50-LEVEL



Horizontal grid spacing required to ensure there are at least 2 grid points for the first baroclinic deformation radius

Hallberg (2013), *Ocean Modelling*

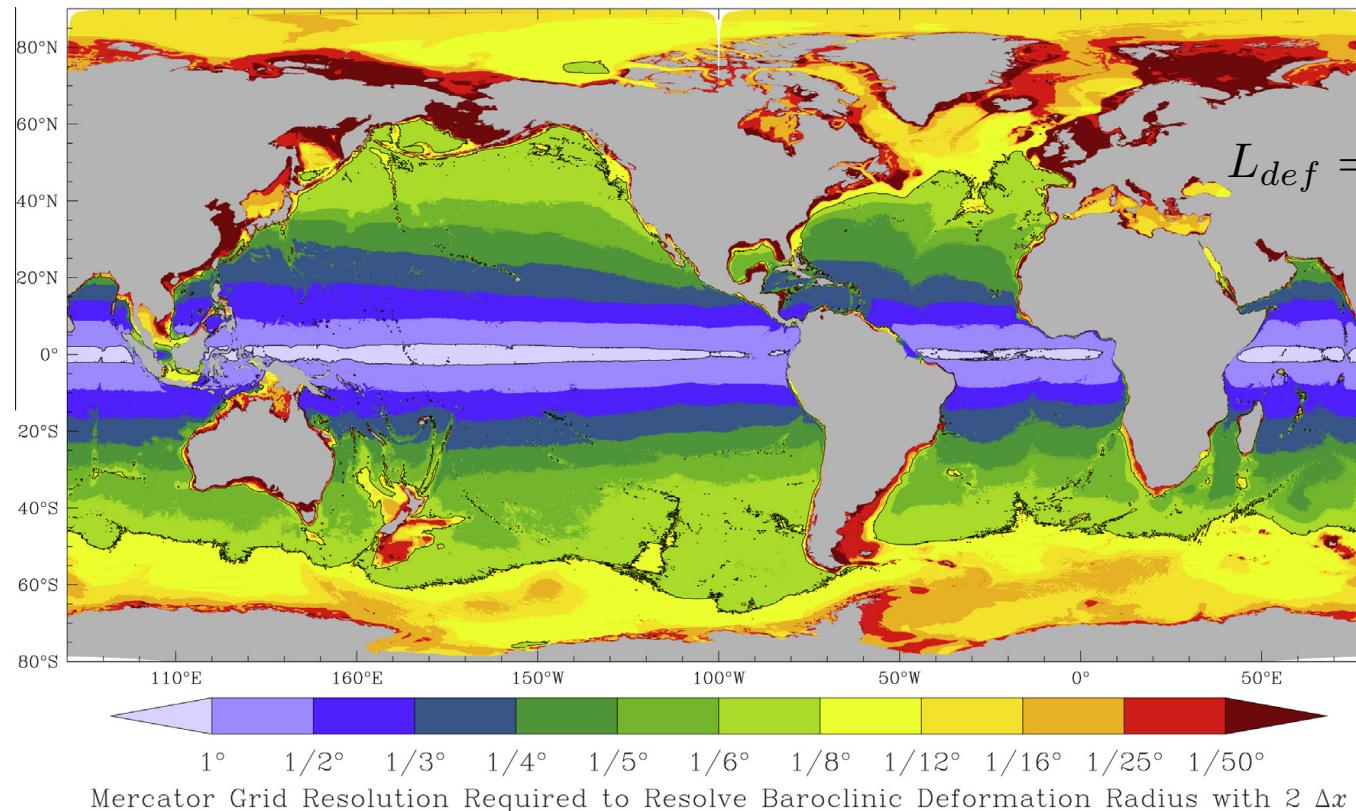


$$L_{def} = \sqrt{\frac{c_m^2}{(f^2 + 2\beta c_m)}}$$

$$\Delta x < a * L_{def}$$

Horizontal grid spacing required to ensure there are at least 2 grid points for the first baroclinic deformation radius

Hallberg (2013), *Ocean Modelling*



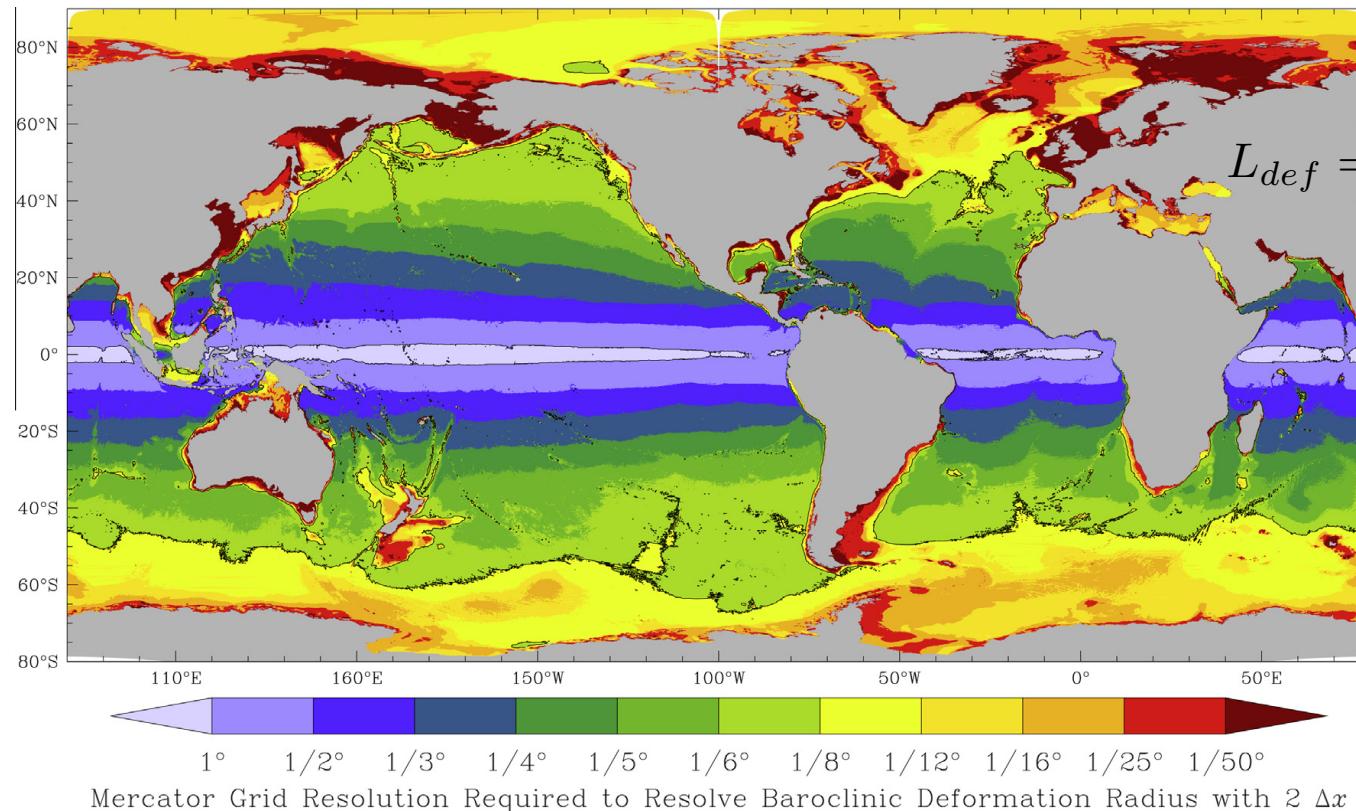
$$L_{def} = \sqrt{\frac{c_m^2}{(f^2 + 2\beta c_m)}}$$

$$\Delta x < a * L_{def}$$

What vertical resolution is needed?

Horizontal grid spacing required to ensure there are at least 2 grid points for the first baroclinic deformation radius

Hallberg (2013), *Ocean Modelling*



What vertical resolution is needed?

How do we know if the vertical grid is appropriate for the horizontal grid?

What vertical resolution is needed?

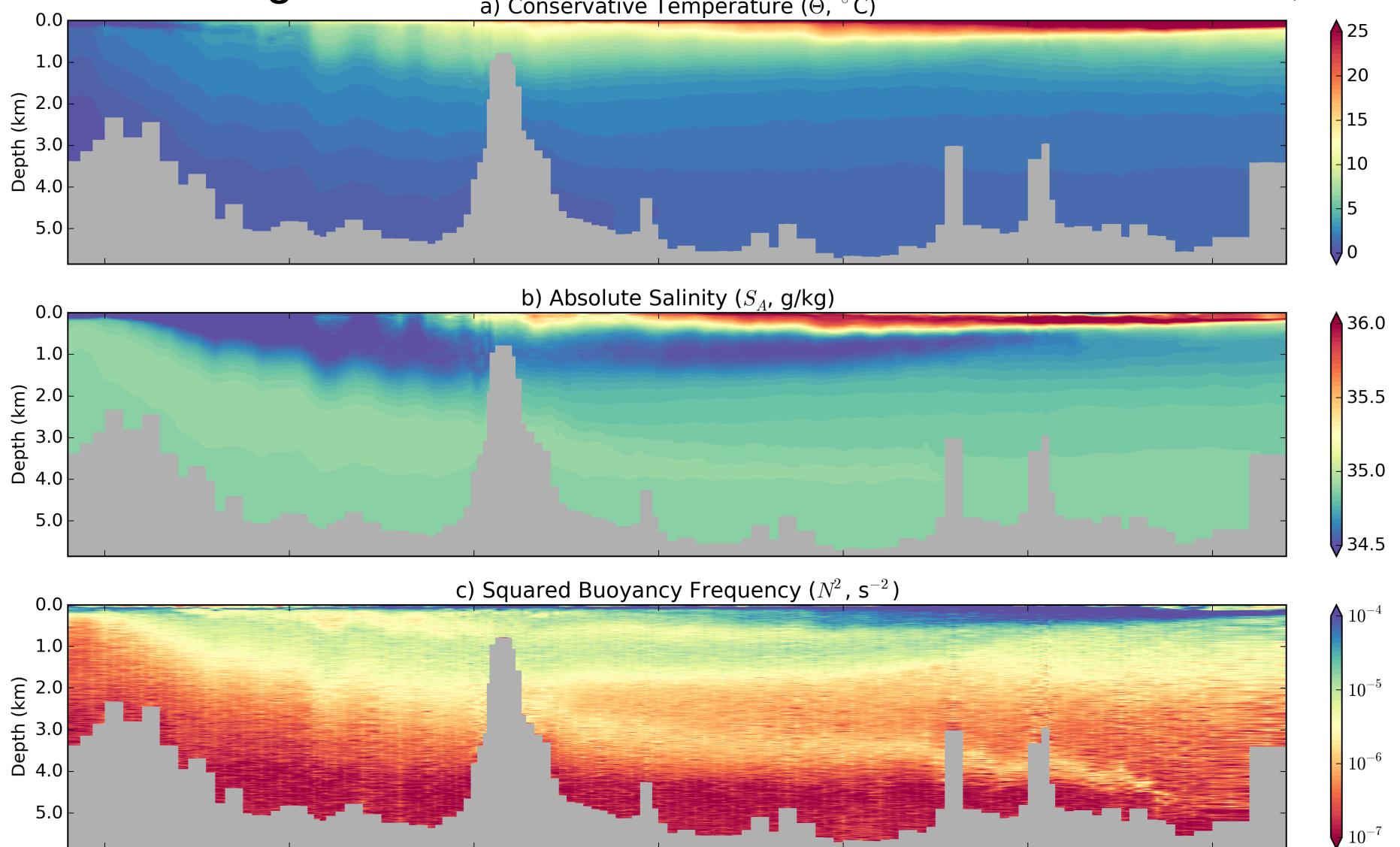
The primary purpose of the vertical grid is to capture the vertical structure of horizontal flows.

What vertical resolution is needed?

The primary purpose of the vertical grid is to capture the vertical structure of horizontal flows.

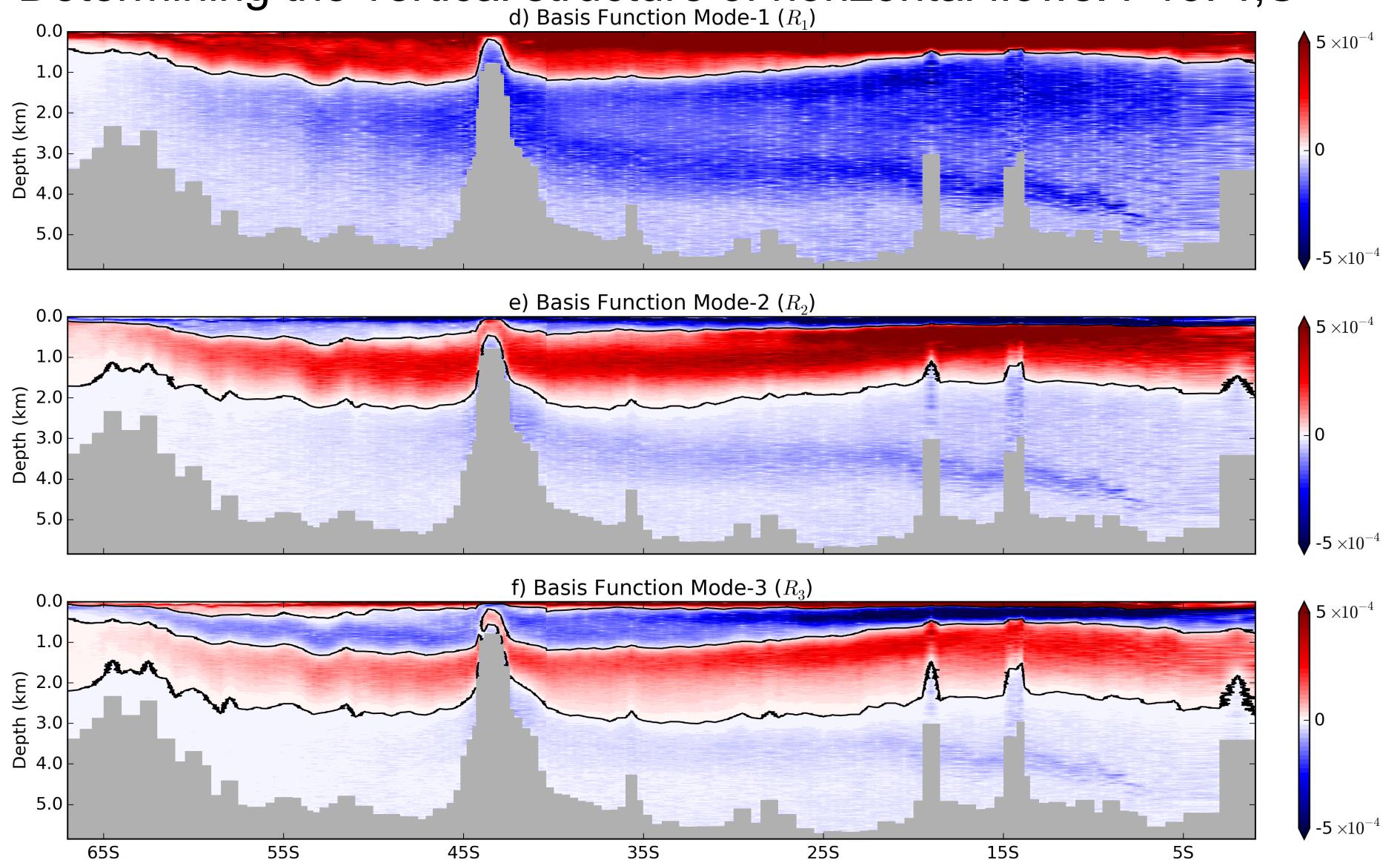
The vertical structure of horizontal flows can be estimated from the baroclinic modal basis functions.

Determining the vertical structure of horizontal flows. P15: T,S



$$N^2 = g \left(\alpha \frac{\partial \Theta}{\partial z} - \beta \frac{\partial S_A}{\partial z} \right)$$

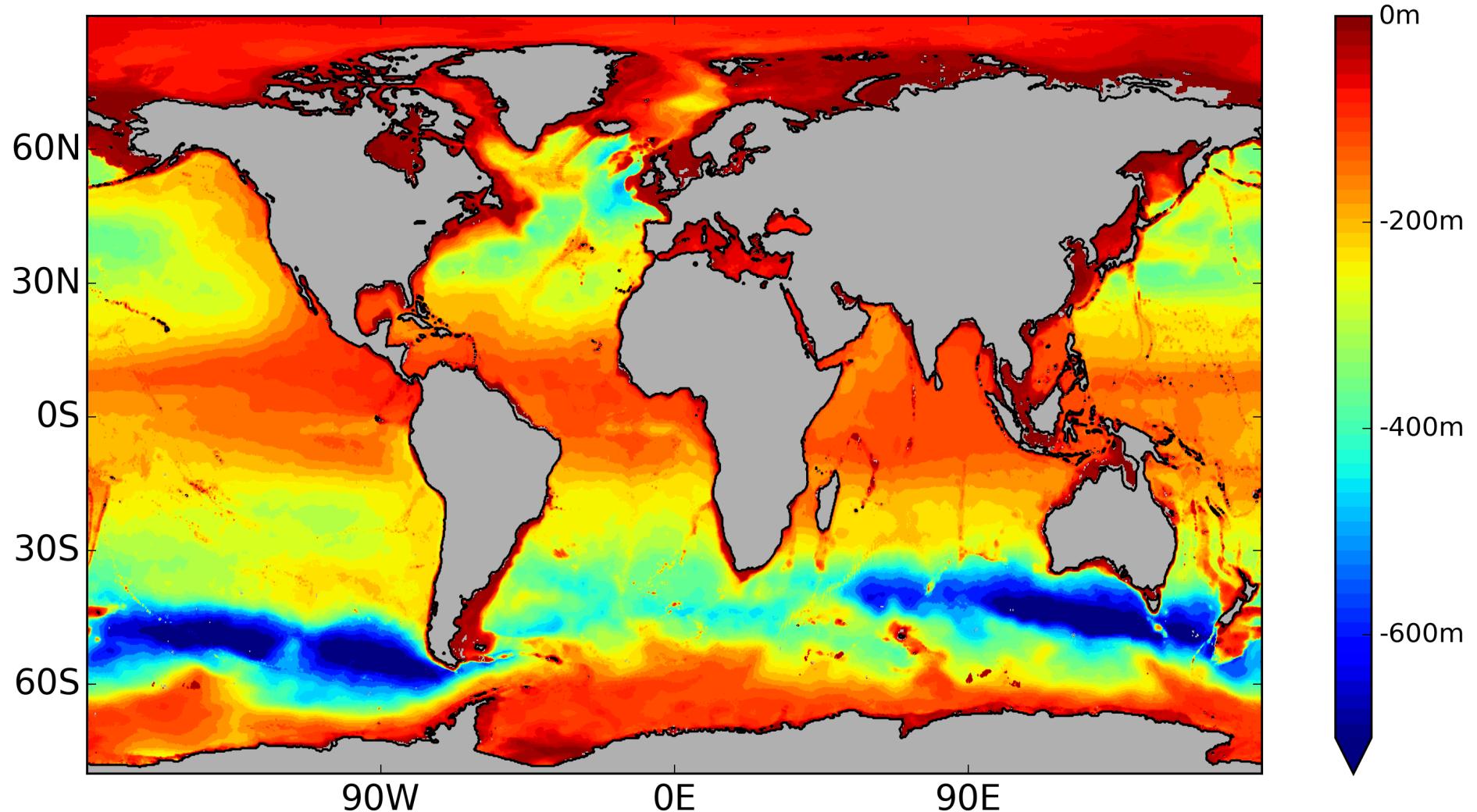
Determining the vertical structure of horizontal flows. P15: T,S



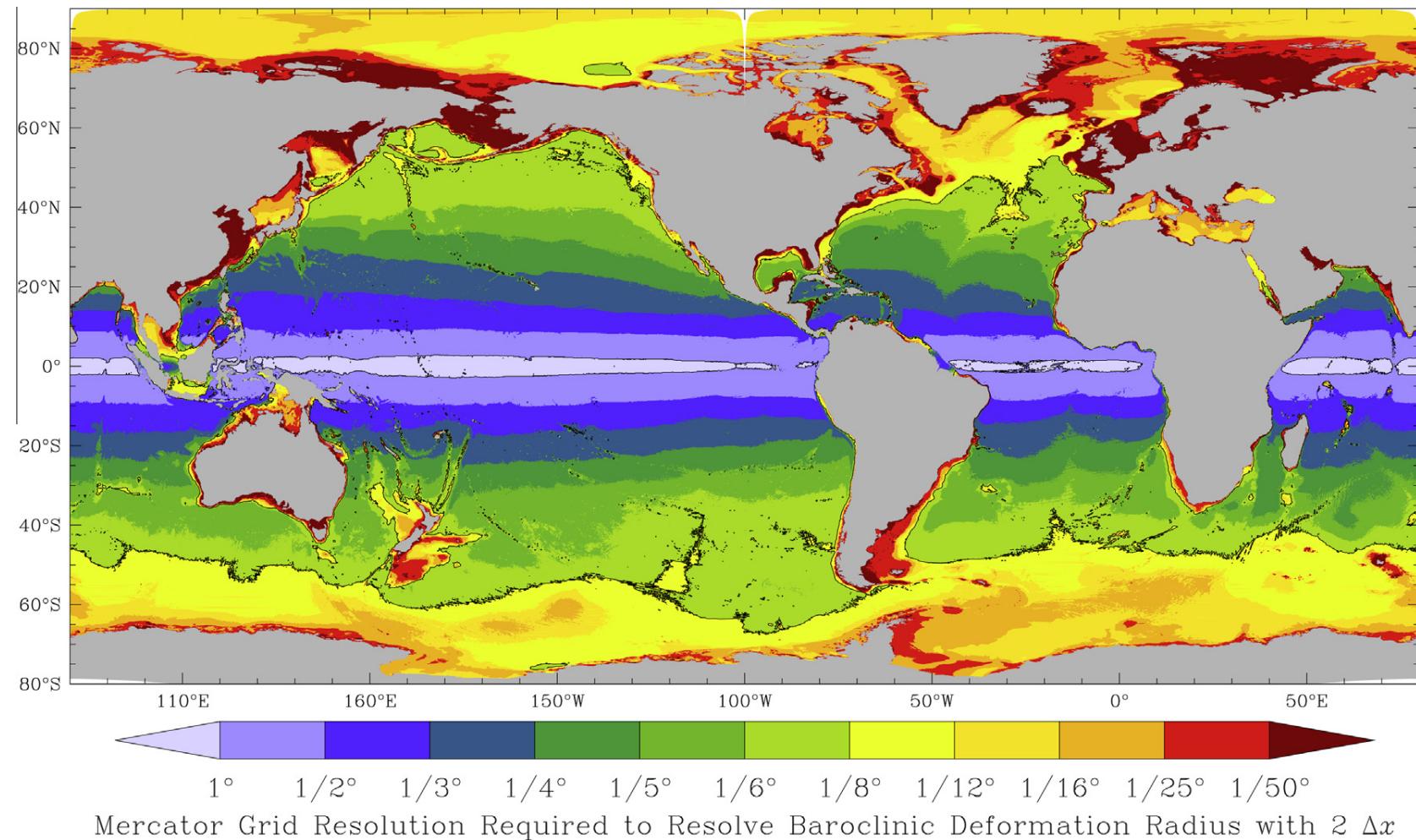
$$R_m(z) = - \left(\frac{c_m N(z)}{g} \right) \cos \left(\frac{1}{c_m} \int_{-H}^z N(z) dz \right)$$

Zero crossing distribution: $h_{2,1}$

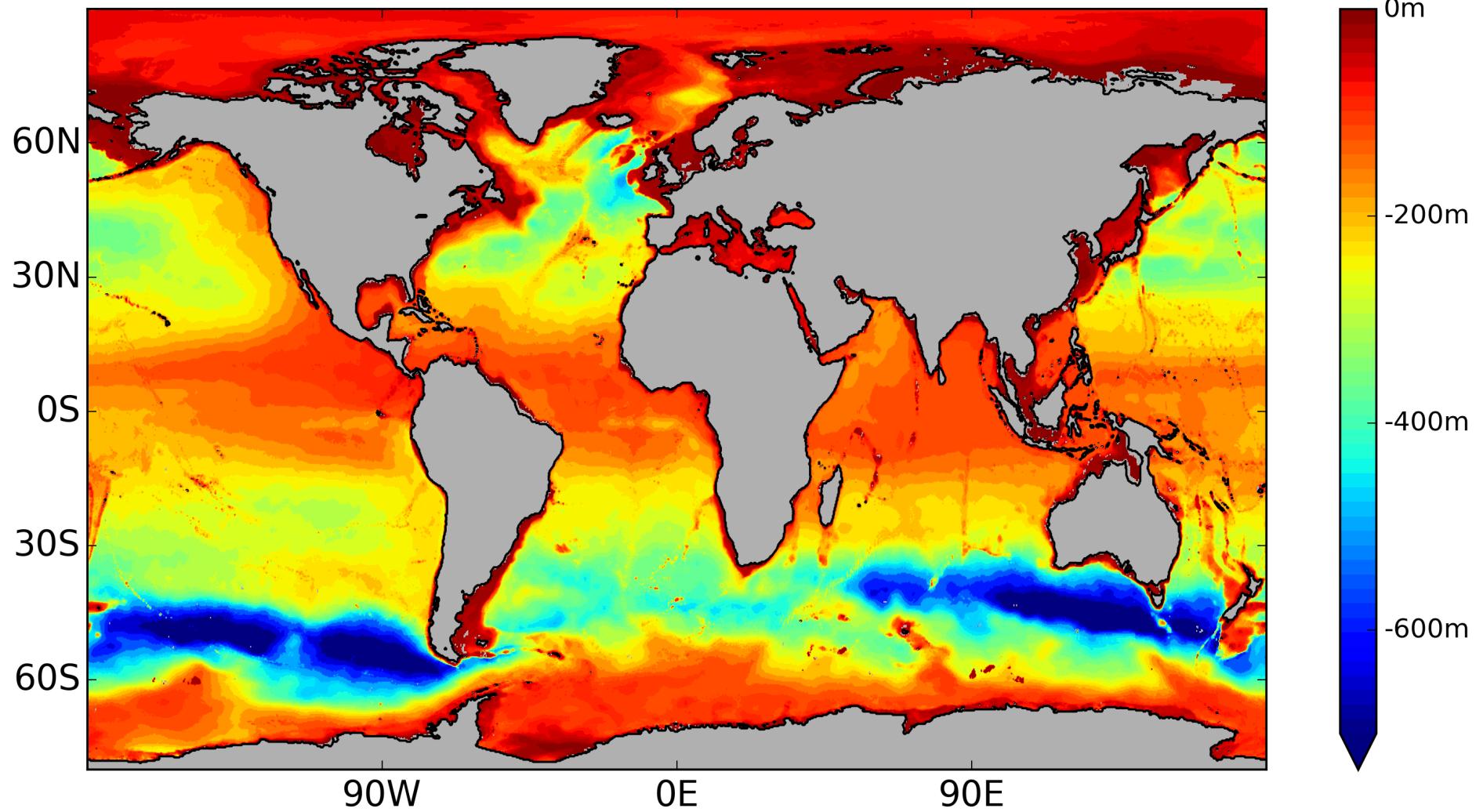
World Ocean Atlas 2013: $h_{2,1}$



Zero crossing distribution: $h_{2,1}$

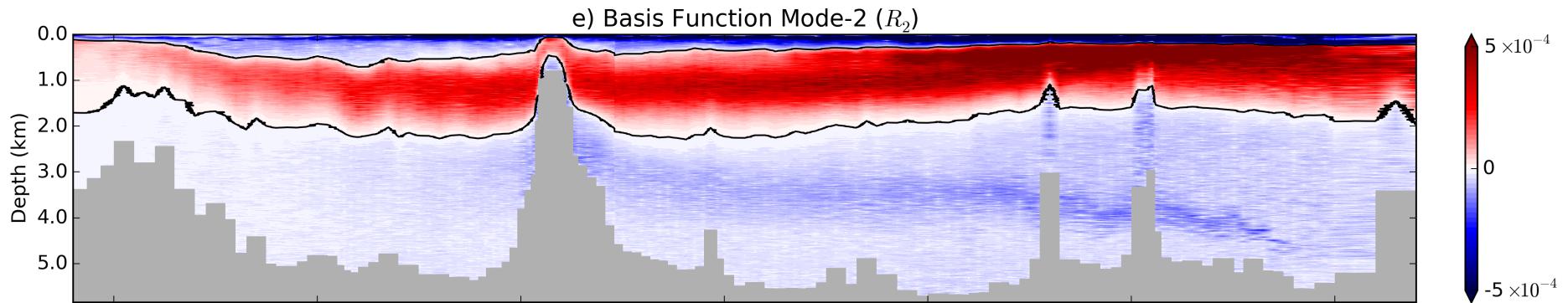


Zero crossing distribution: $h_{2,1}$ – depth & stratification



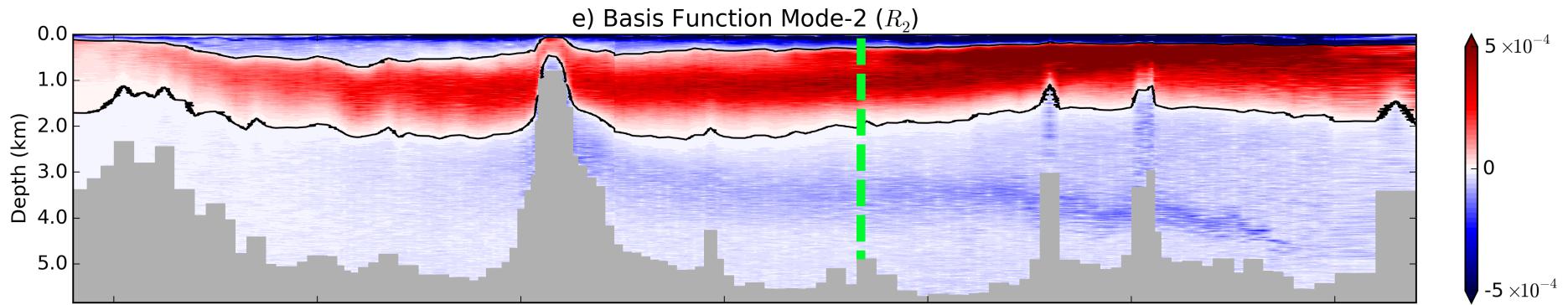
Provides guidance for constructing vertical grids

Determining the vertical structure of horizontal flows. P15: T,S



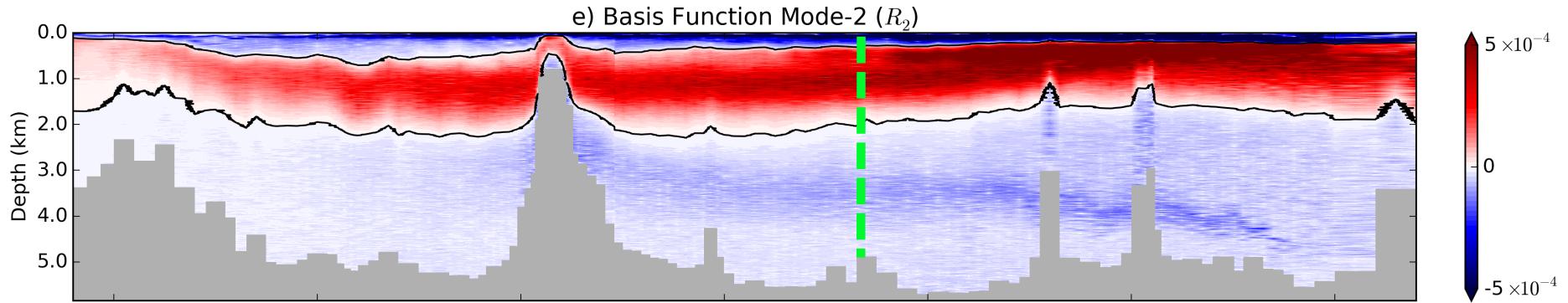
Ensure that
there are 3
vertical grid
points
between zero
crossings

Determining the vertical structure of horizontal flows. P15: T,S

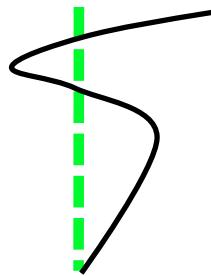


Ensure that
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vertical grid
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crossings

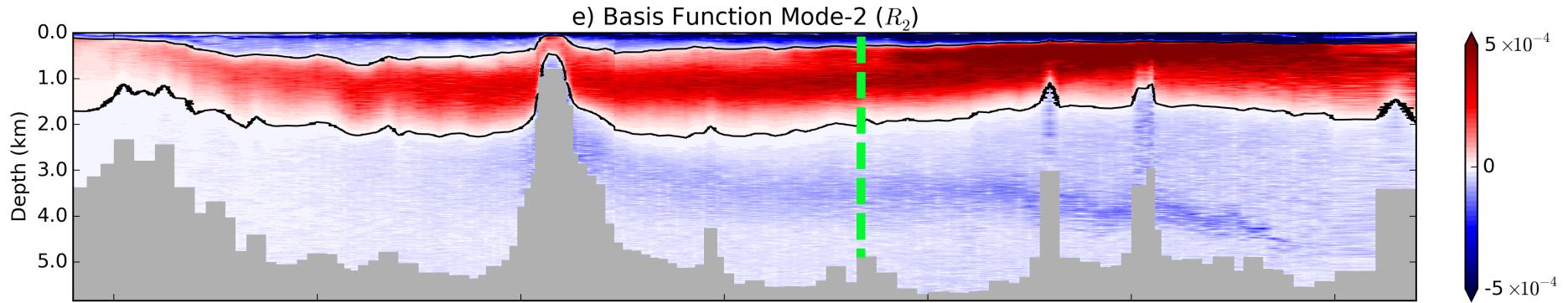
Determining the vertical structure of horizontal flows. P15: T,S



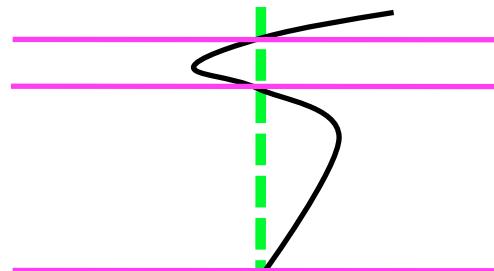
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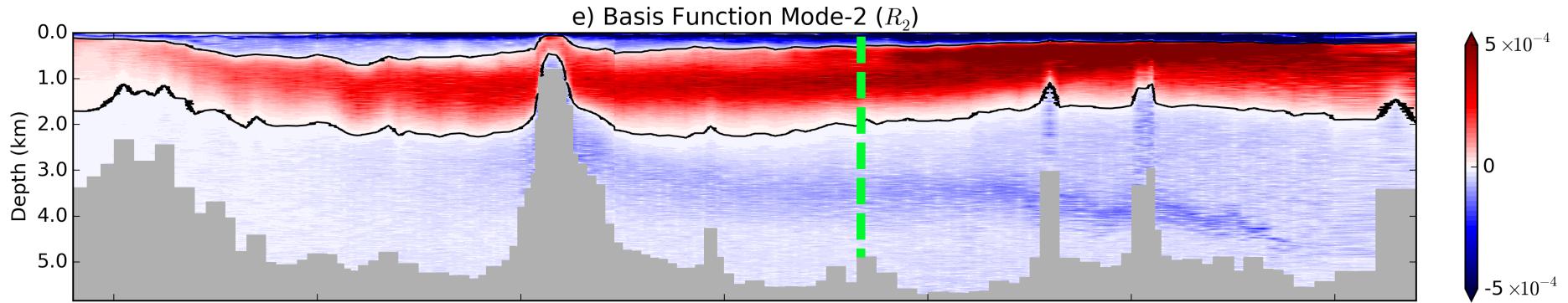
Determining the vertical structure of horizontal flows. P15: T,S



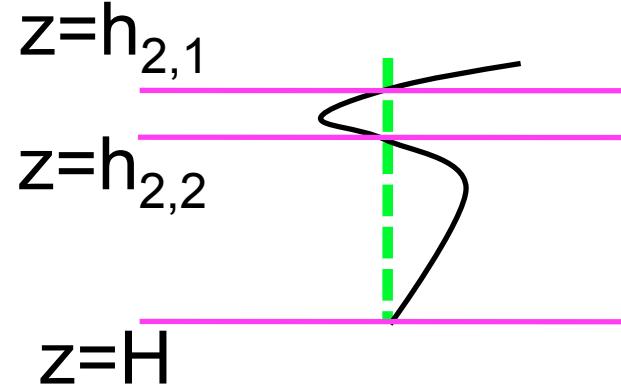
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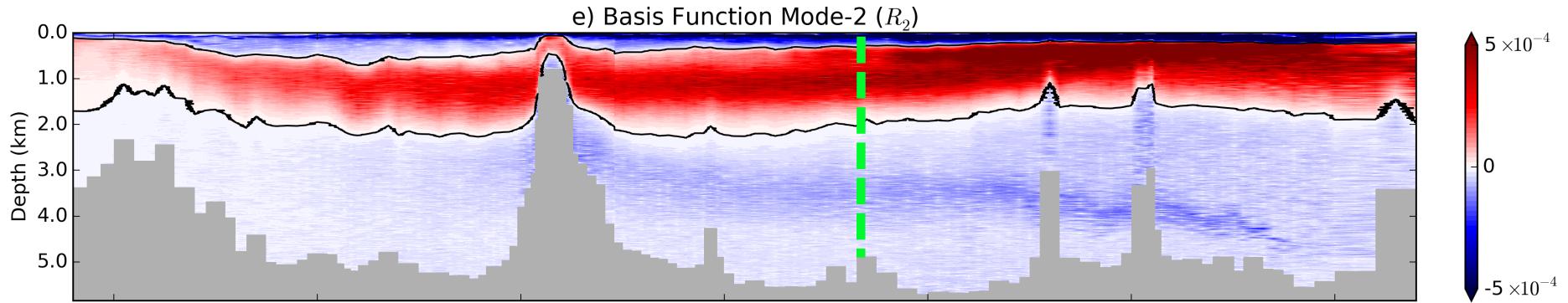
Determining the vertical structure of horizontal flows. P15: T,S



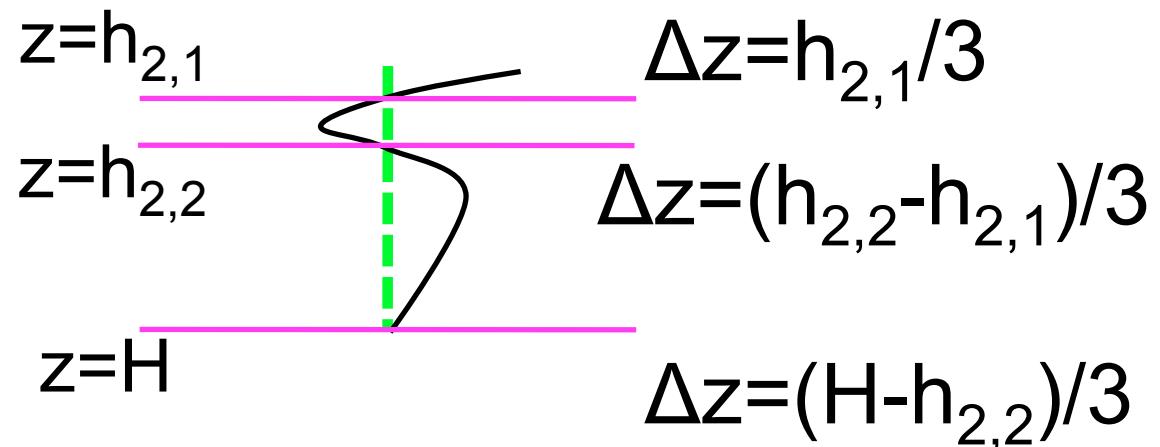
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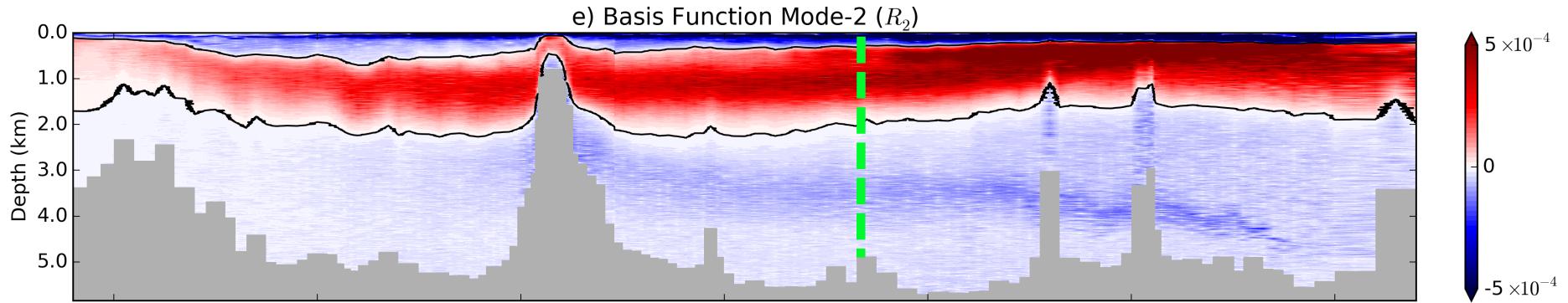
Determining the vertical structure of horizontal flows. P15: T,S



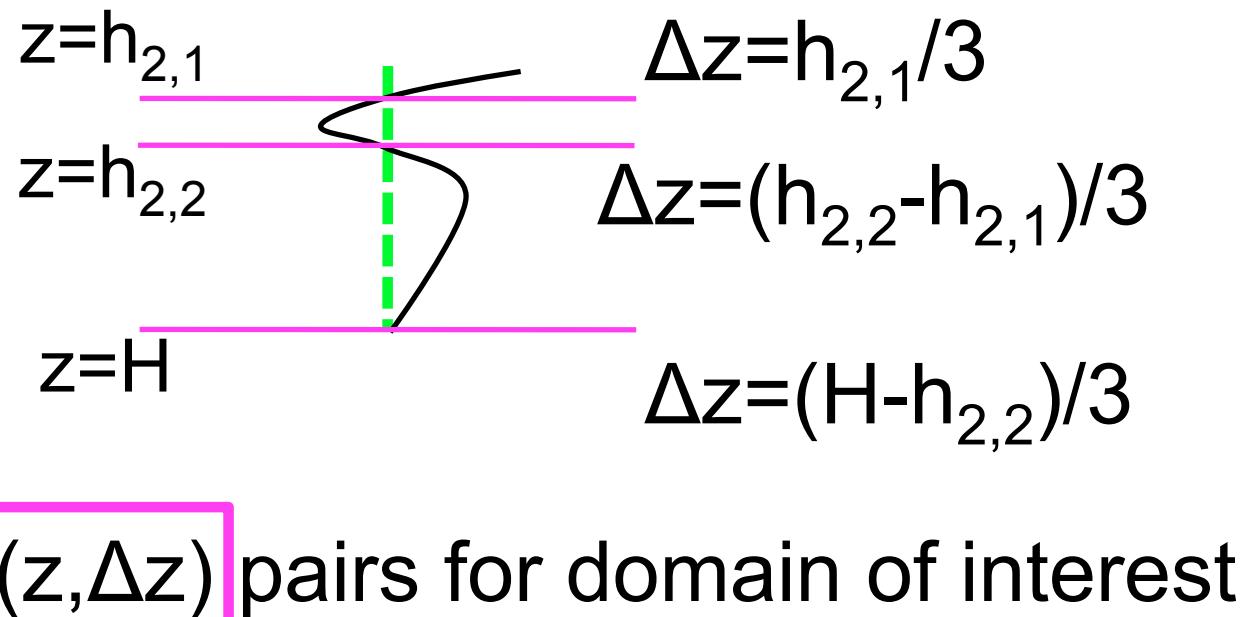
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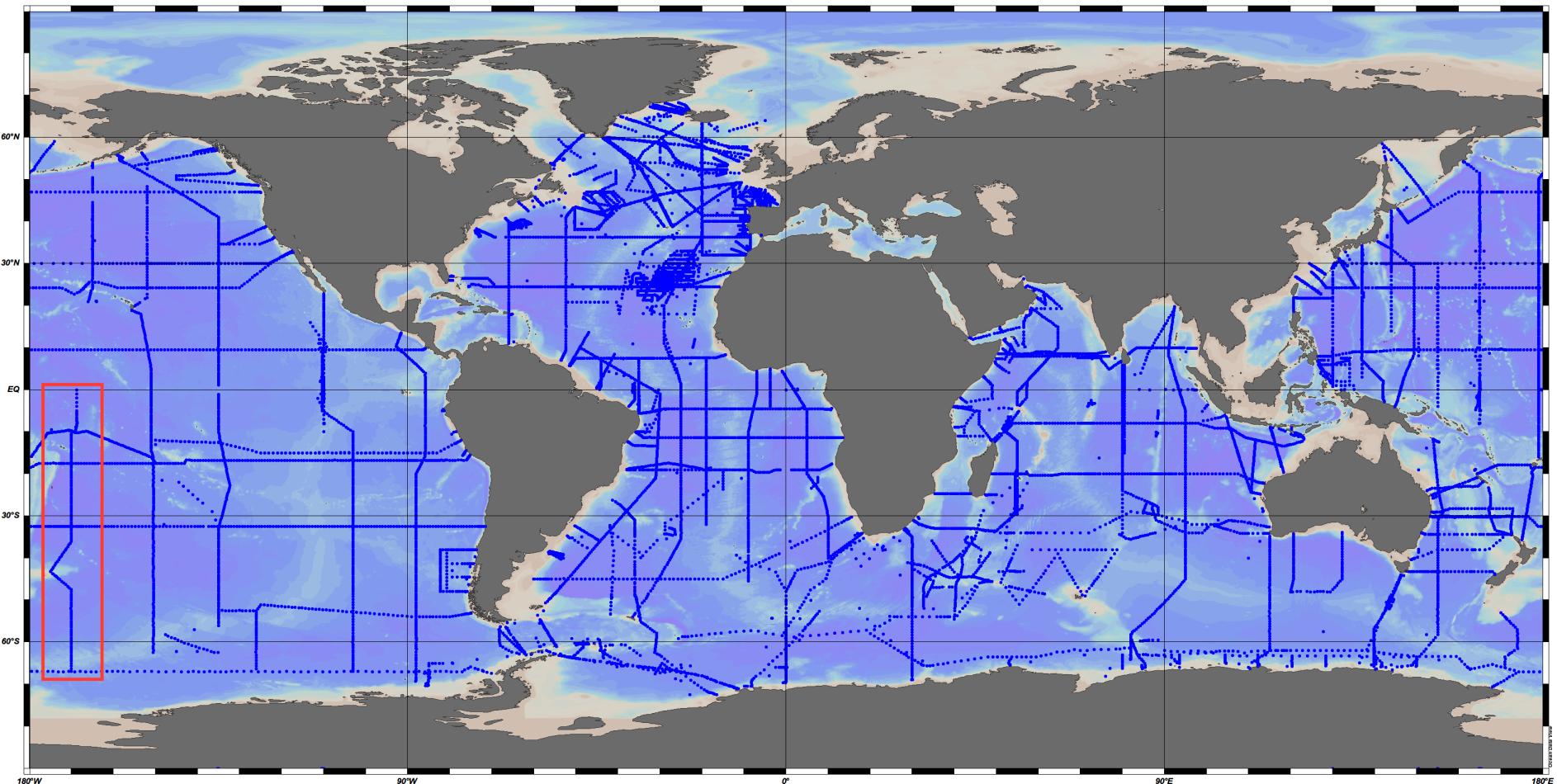
Determining the vertical structure of horizontal flows. P15: T,S



Ensure that
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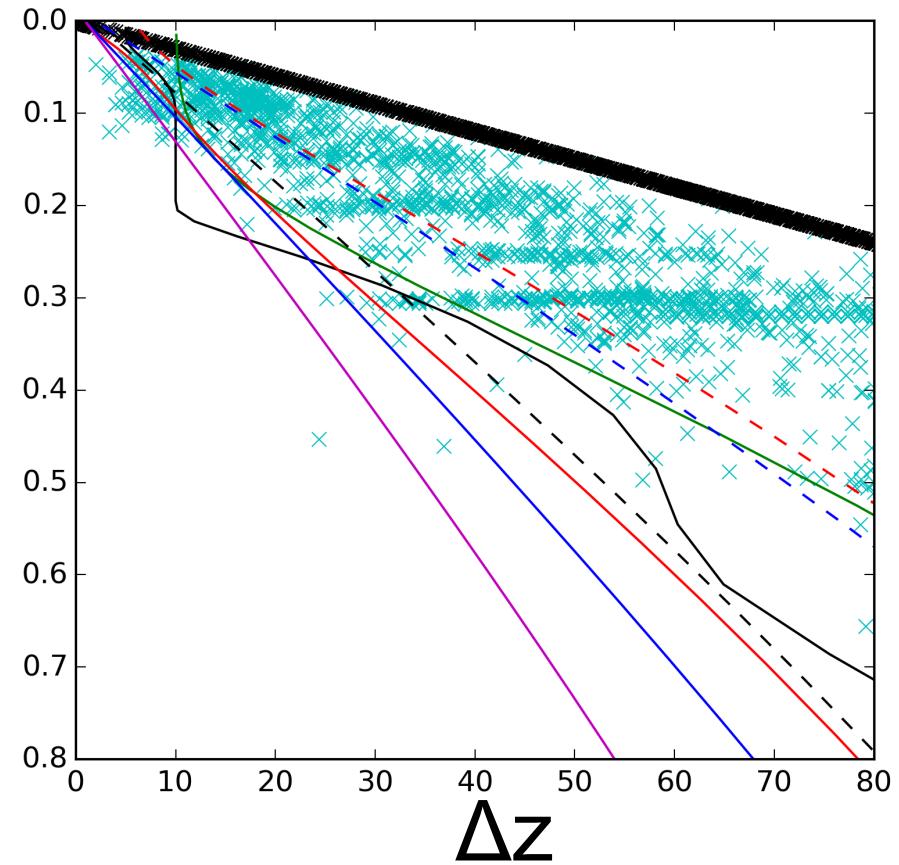
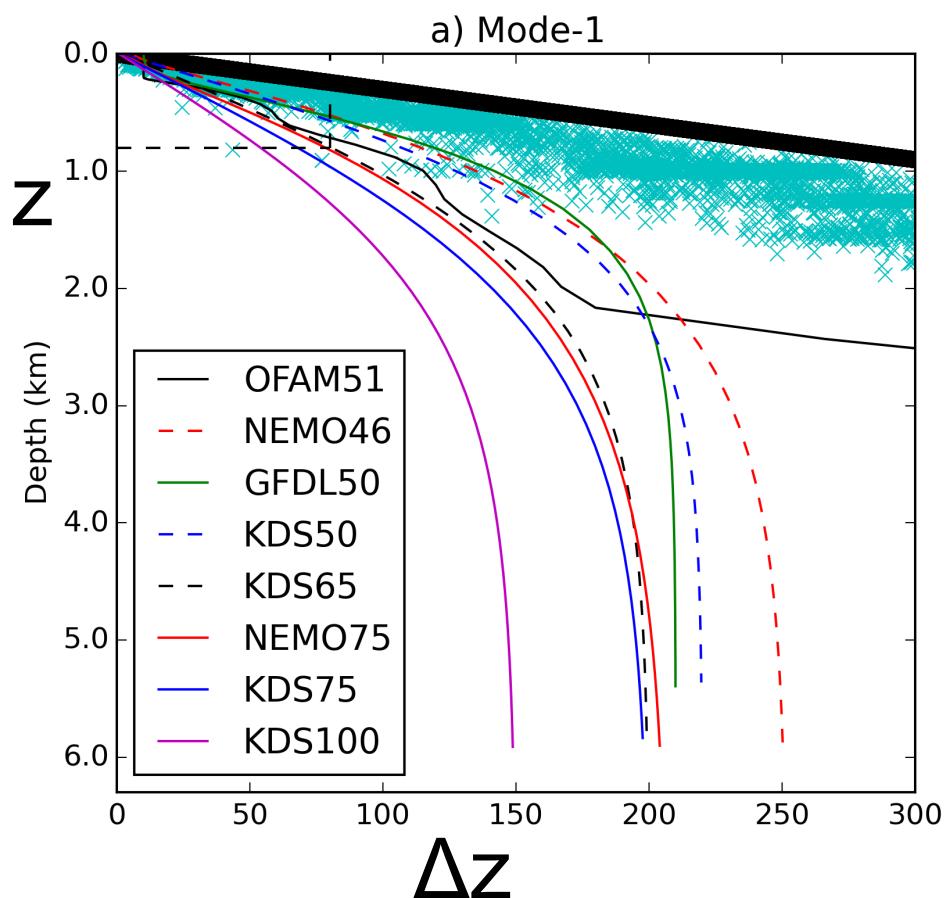


WOCE: 18,000 full-depth CTD profiles

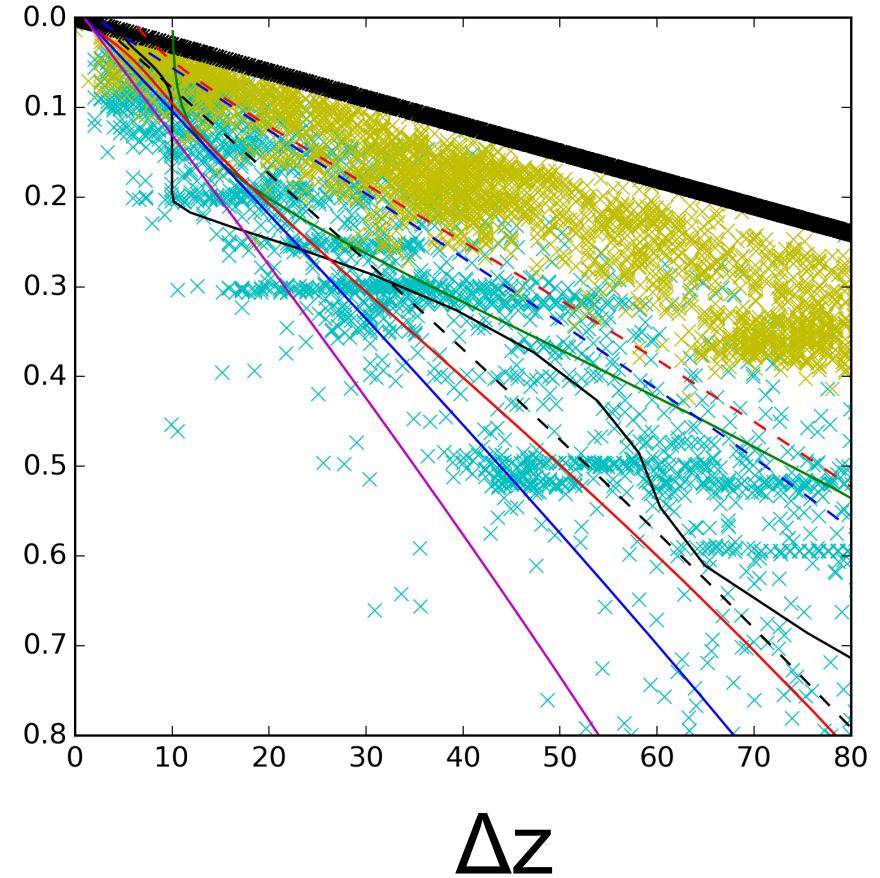
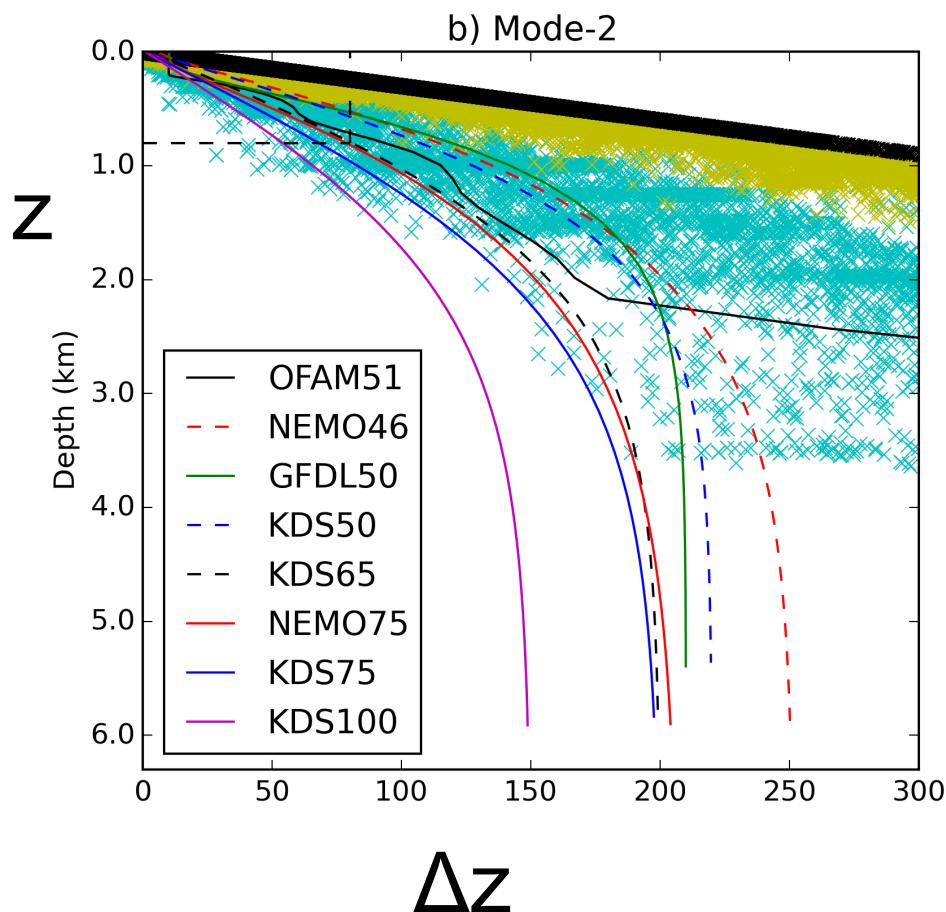


www.ewoce.org

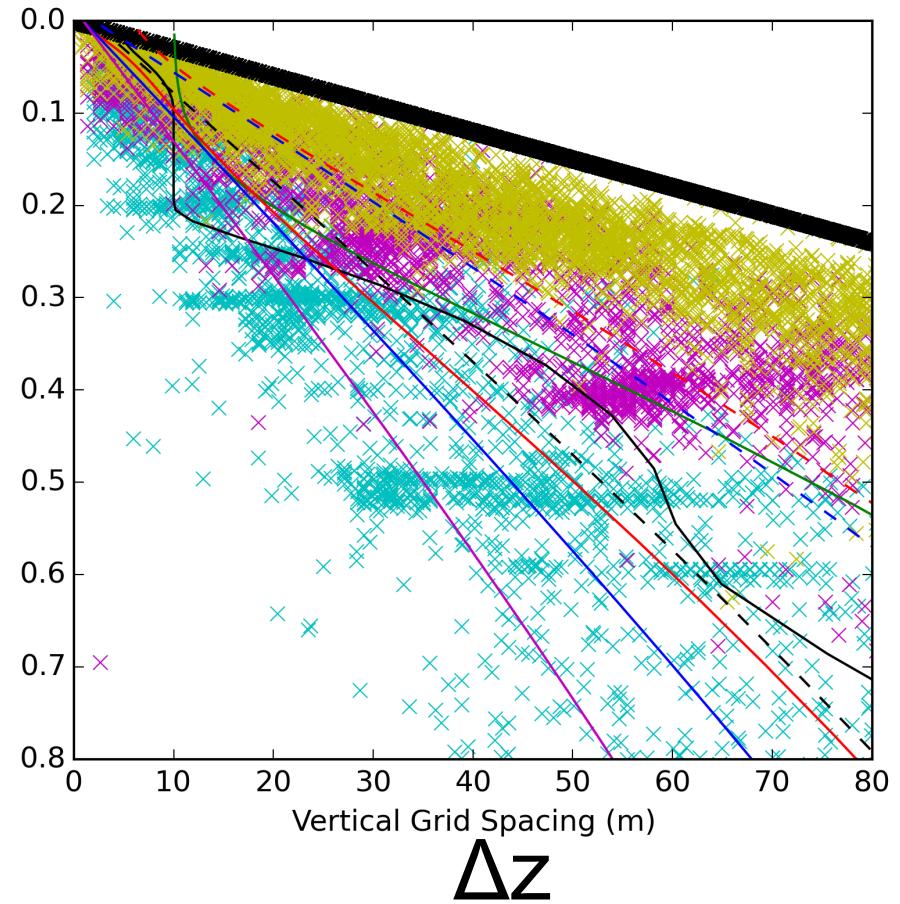
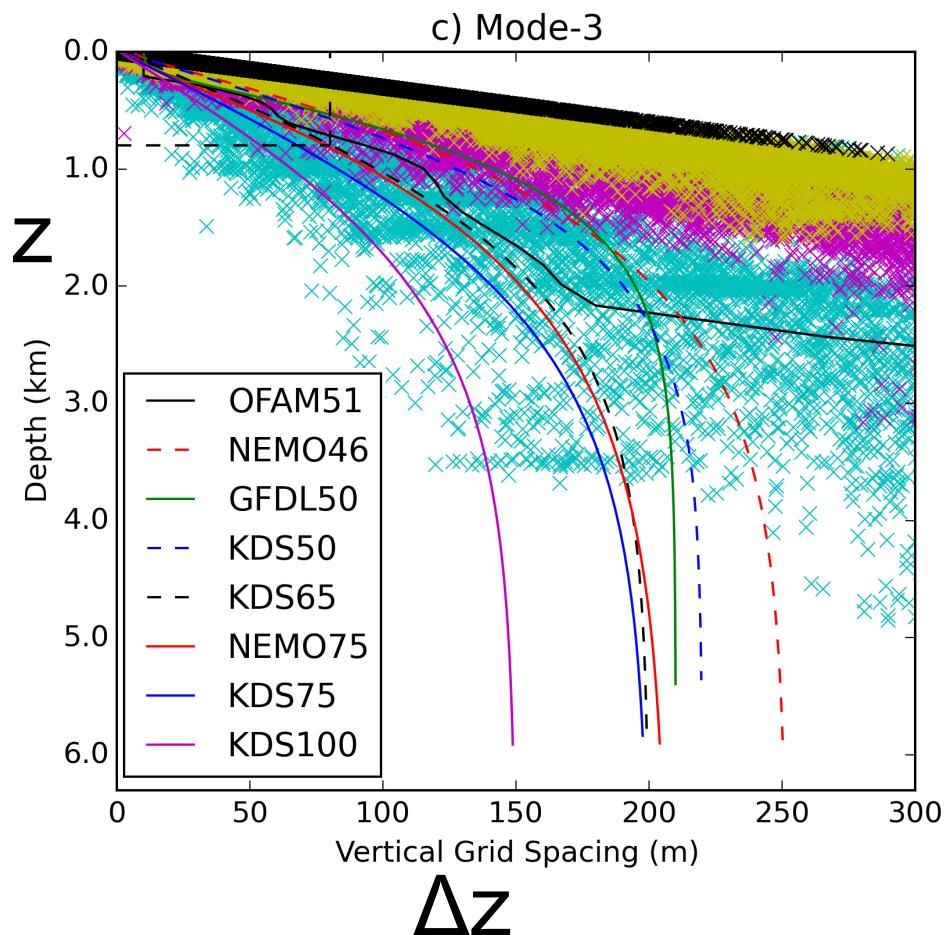
$(z, \Delta z)$ pairs for domain of interest

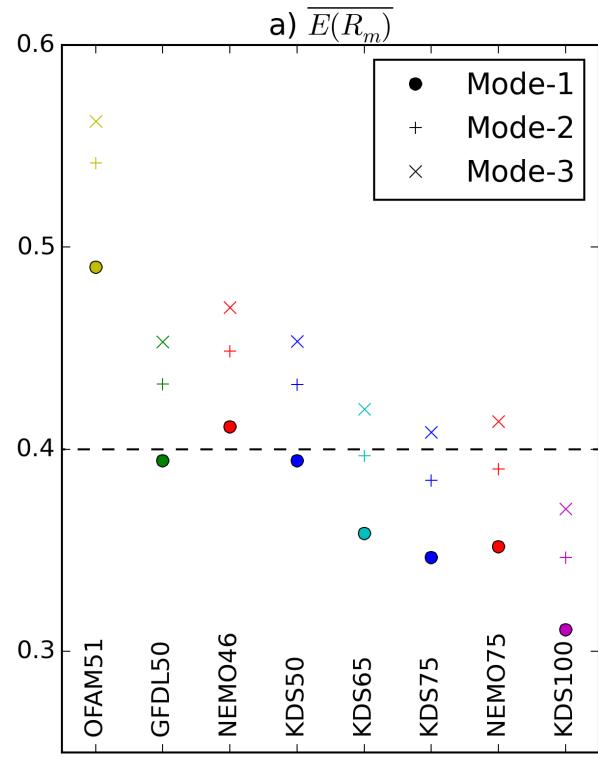


$(z, \Delta z)$ pairs for domain of interest

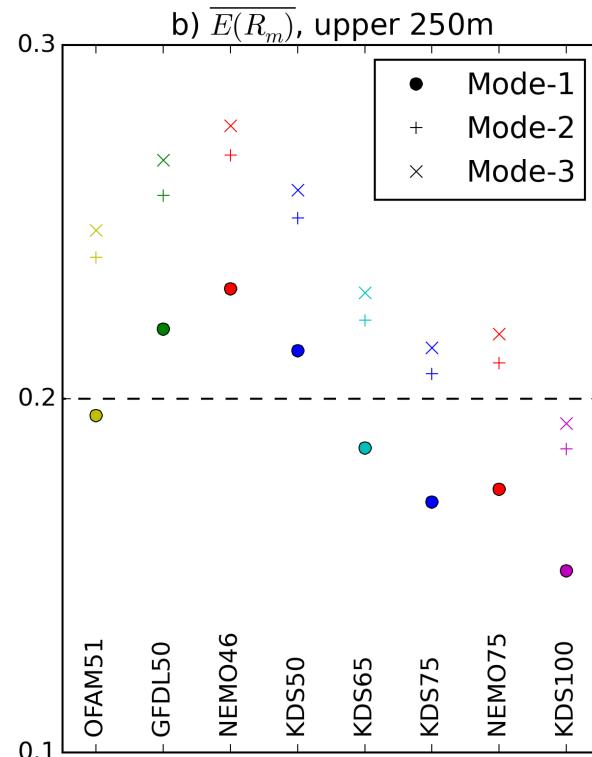


$(z, \Delta z)$ pairs for domain of interest

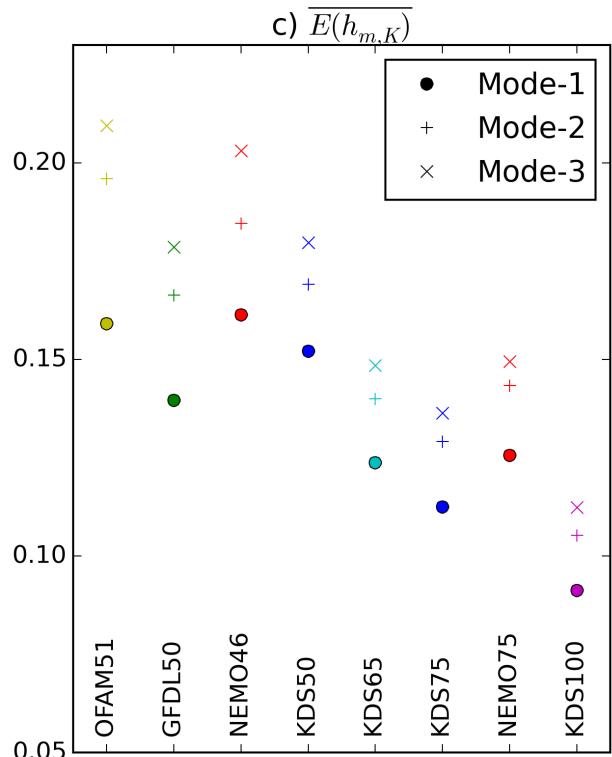




Error of modal structure

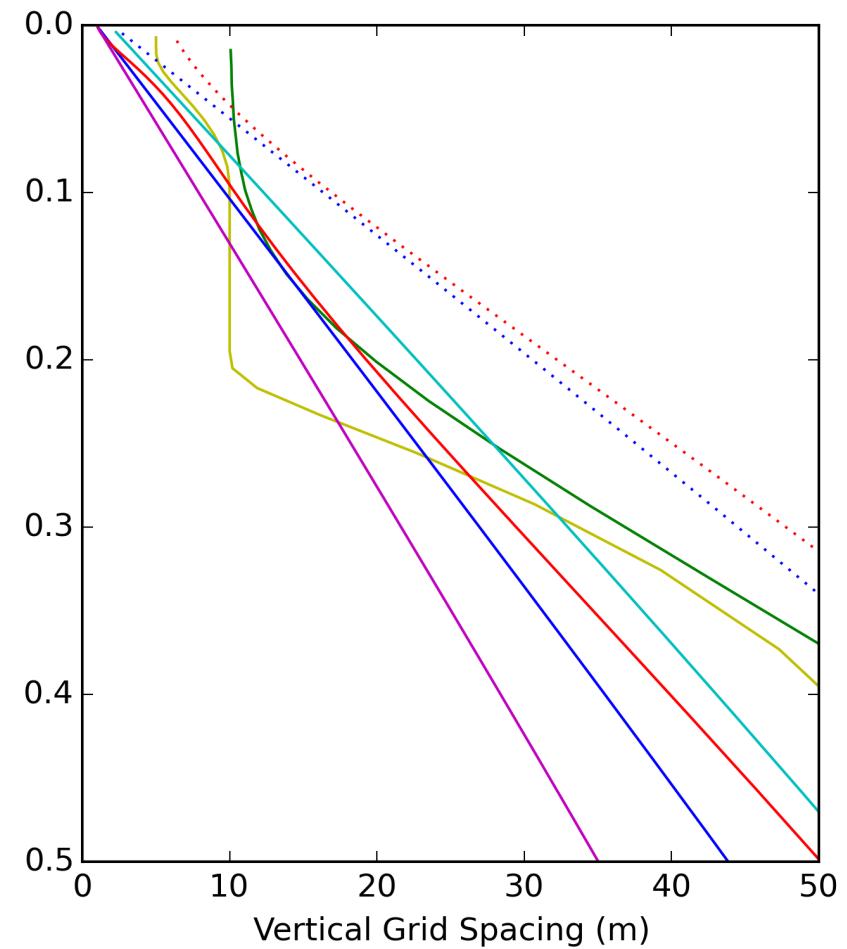
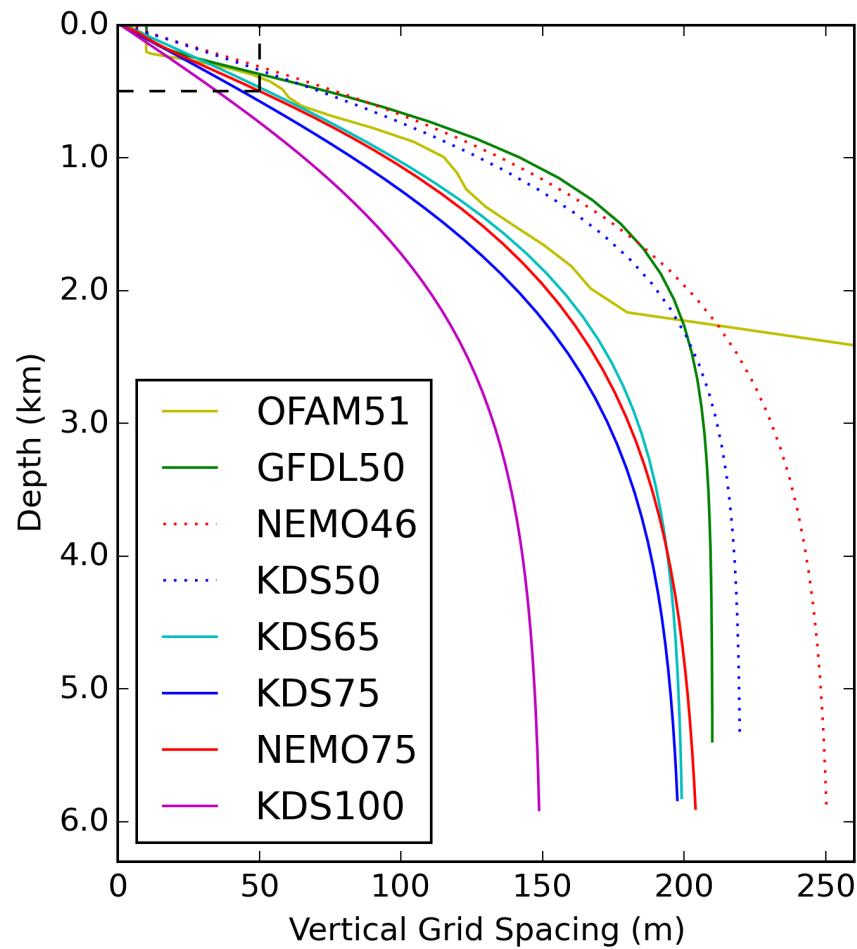


Error of modal structure
upper 250m

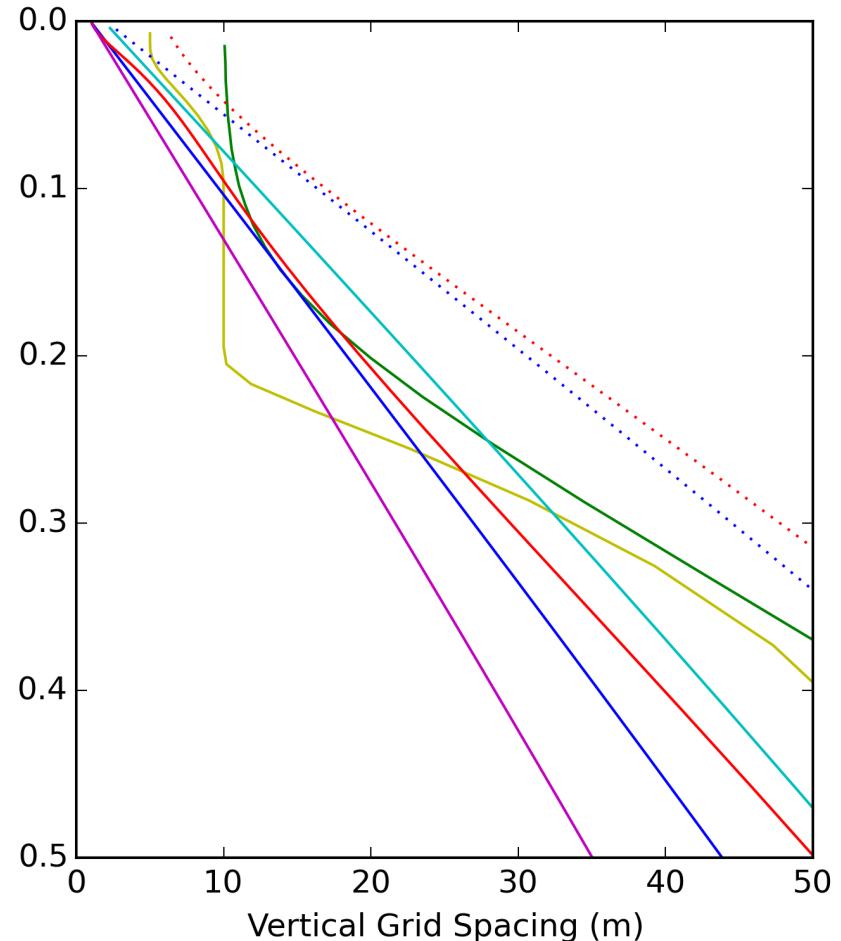
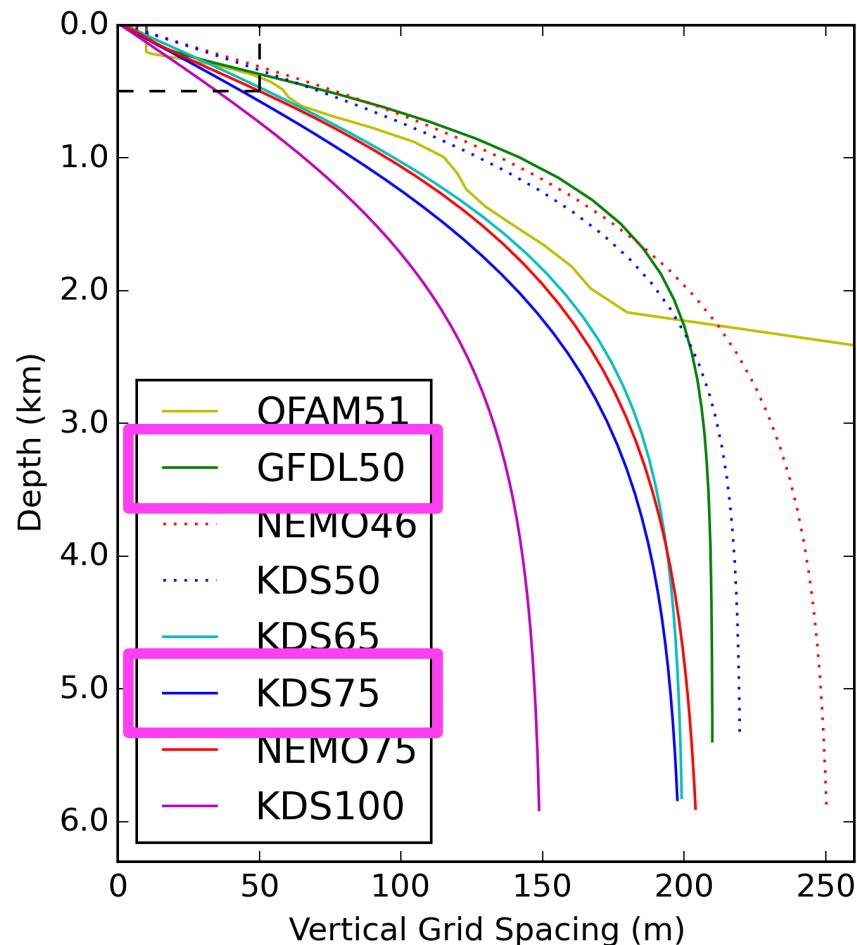


Error of zero crossing
depths

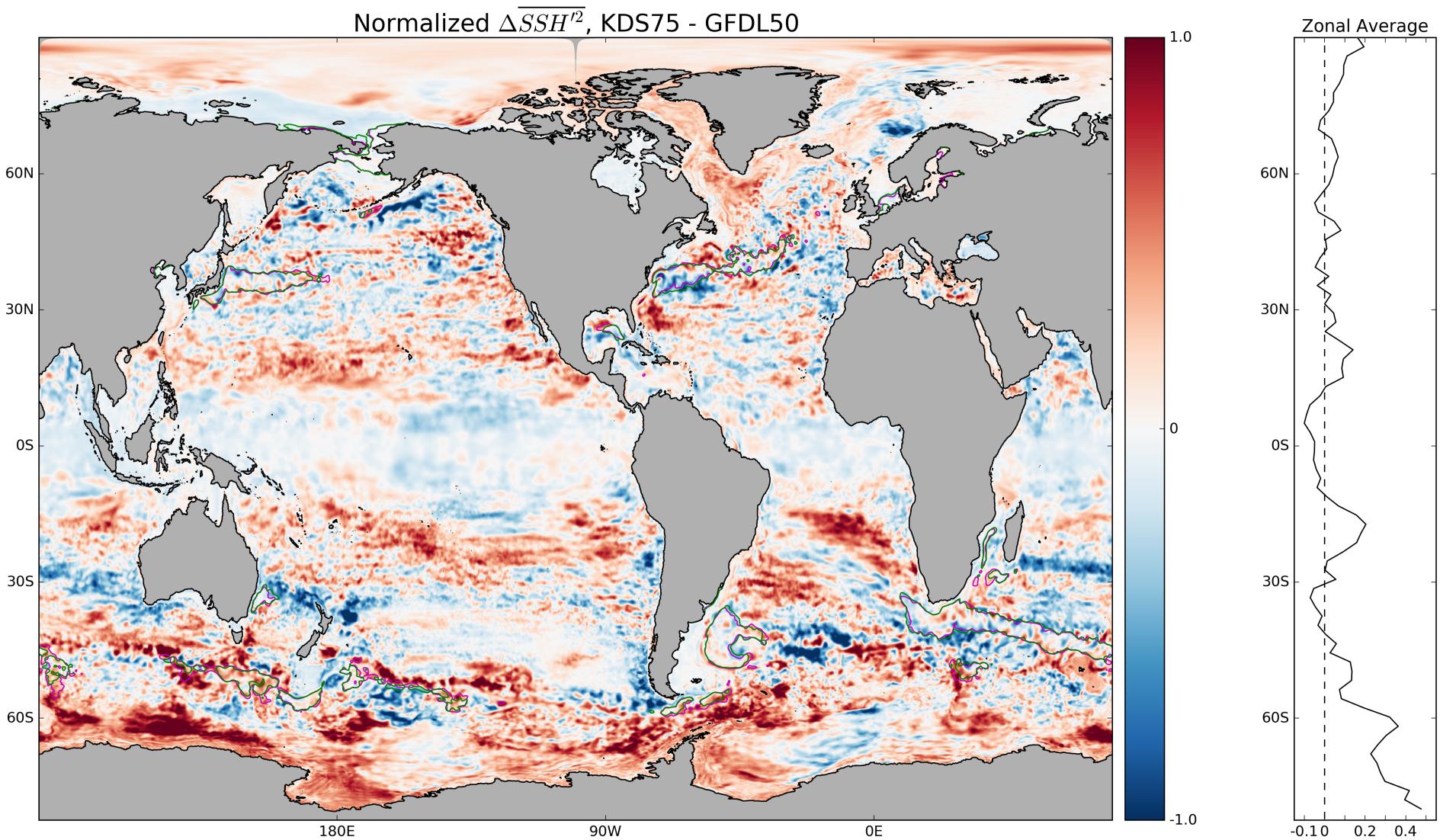
Vertical profiles of vertical grid spacing



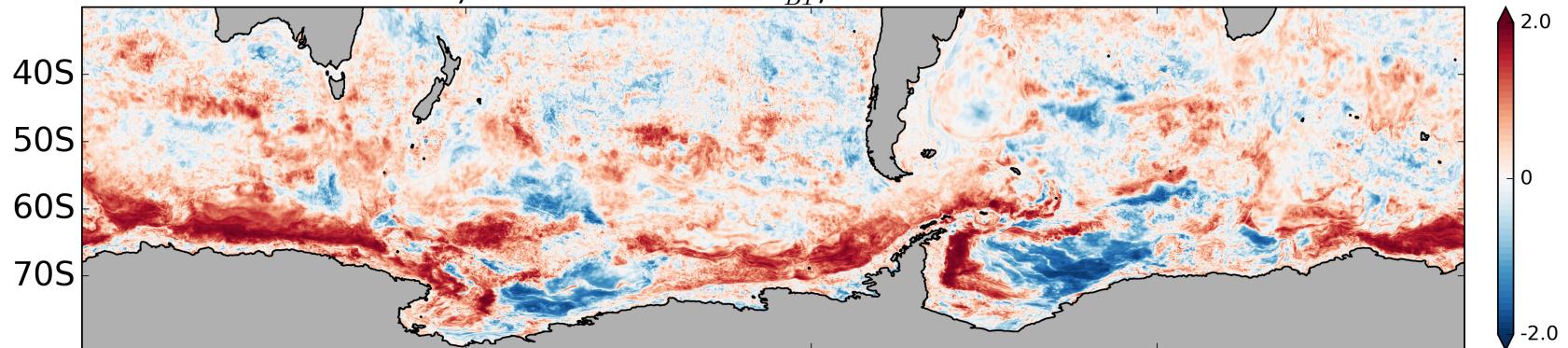
Vertical profiles of vertical grid spacing



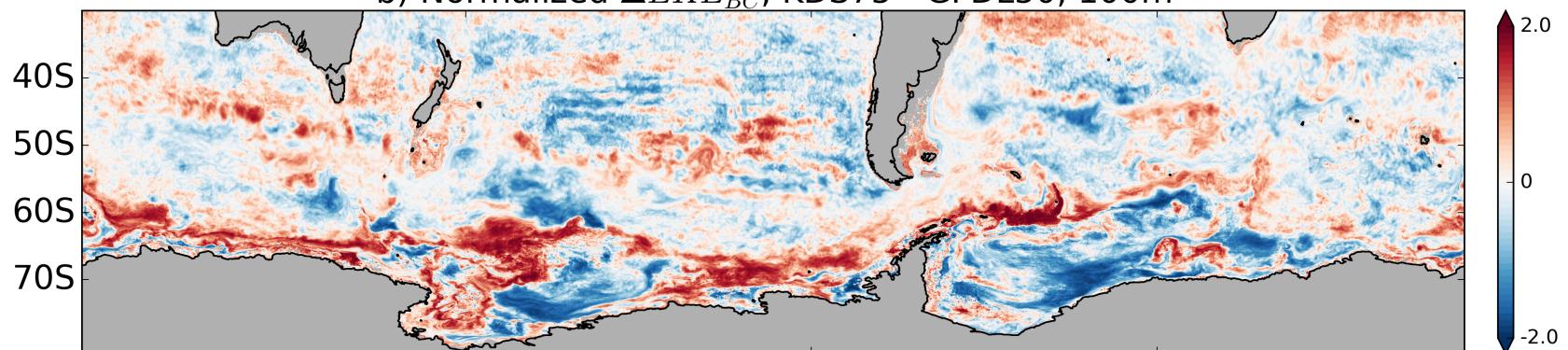
Normalized sea surface height variability difference



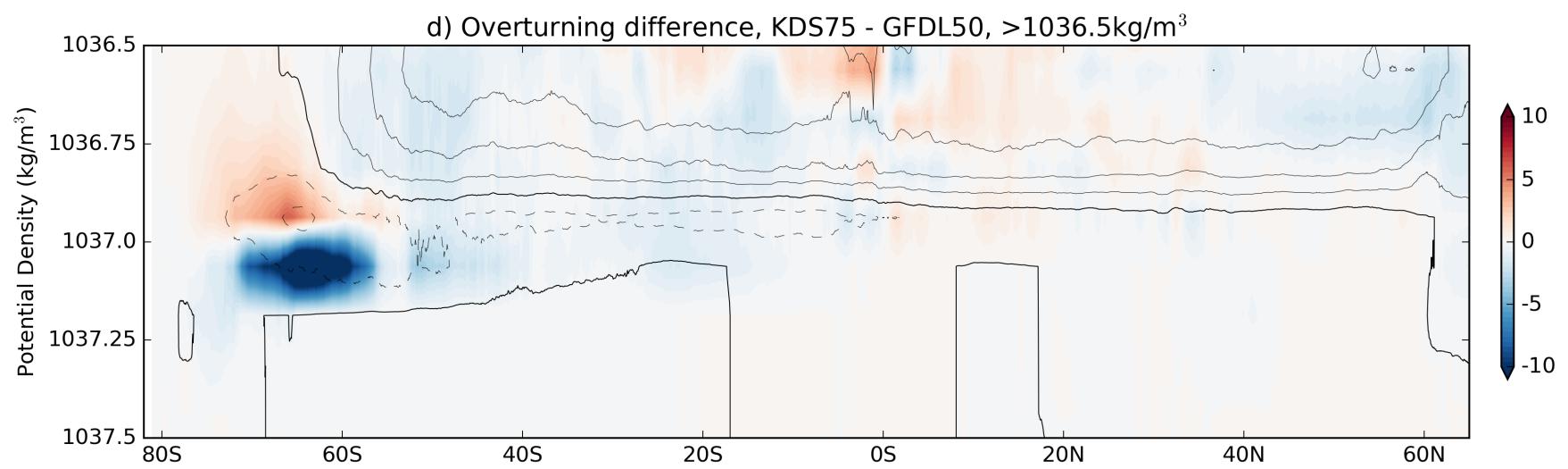
a) Normalized $\overline{\Delta EKE_{BT}}$, KDS75 - GFDL50



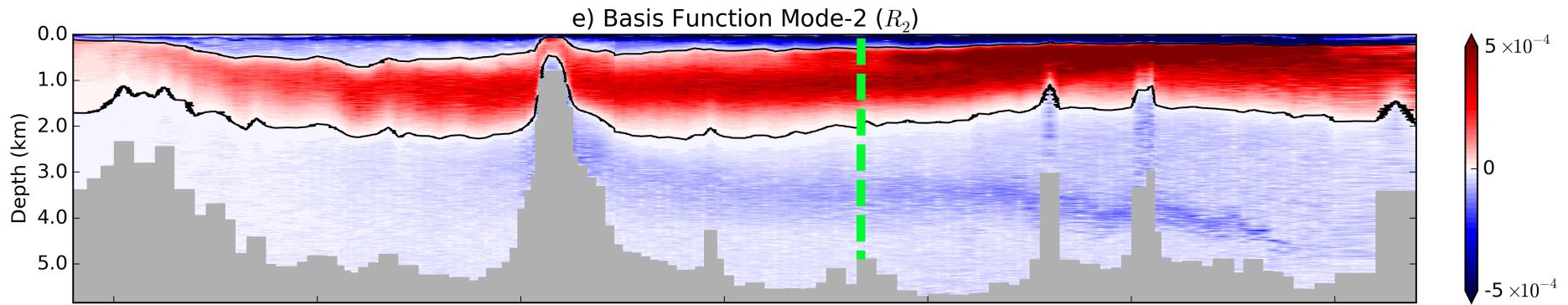
b) Normalized $\overline{\Delta EKE_{BC}}$, KDS75 - GFDL50, 100m



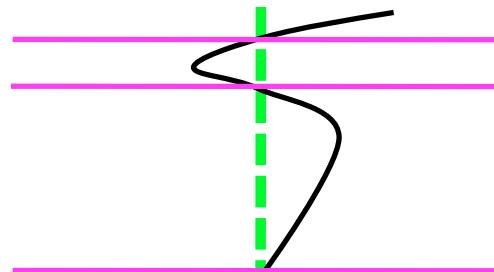
d) Overturning difference, KDS75 - GFDL50, $>1036.5\text{kg/m}^3$



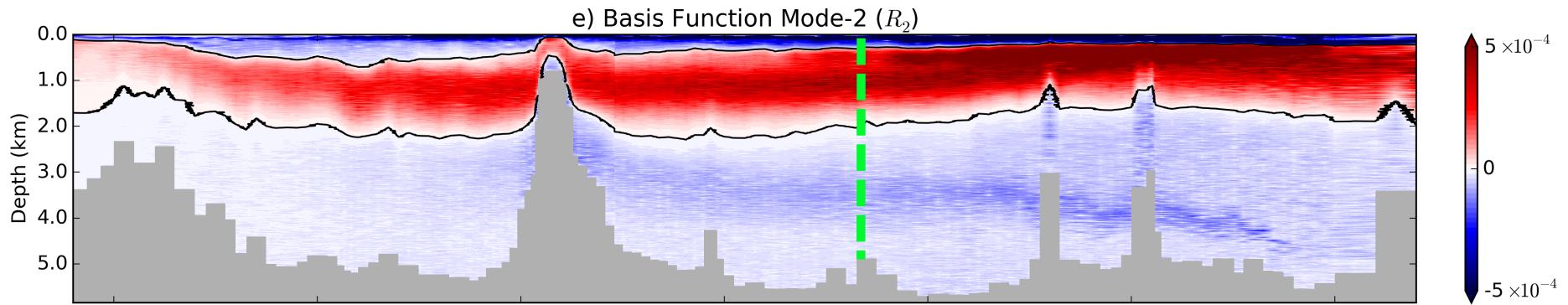
Sigma coordinates????



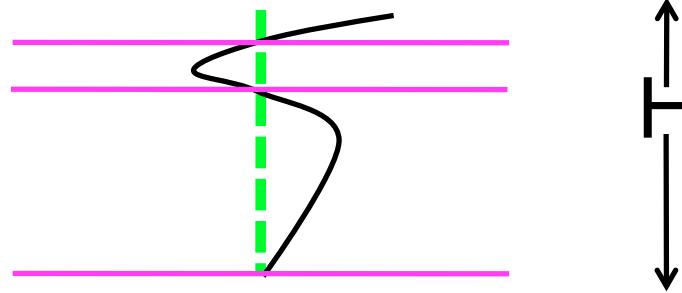
Ensure that
there are 3
vertical grid
points
between zero
crossings



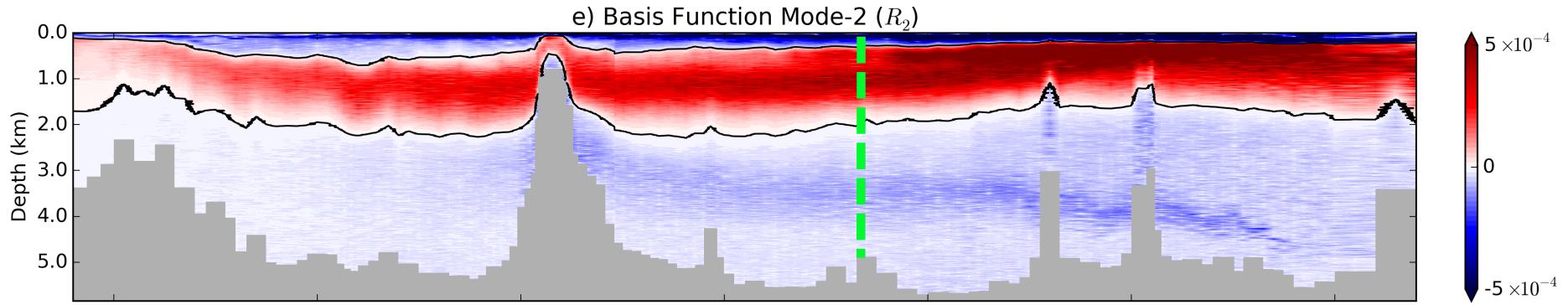
Sigma coordinates????



Ensure that
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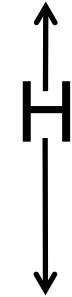
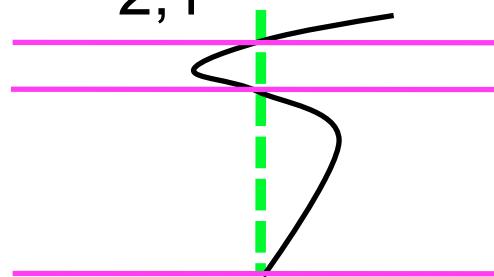


Sigma coordinates????

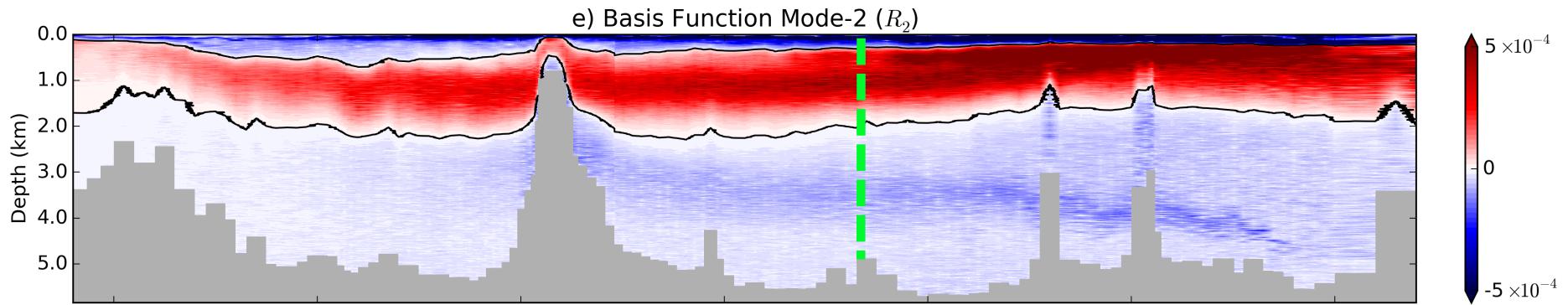


Ensure that there are 3 vertical grid points between zero crossings

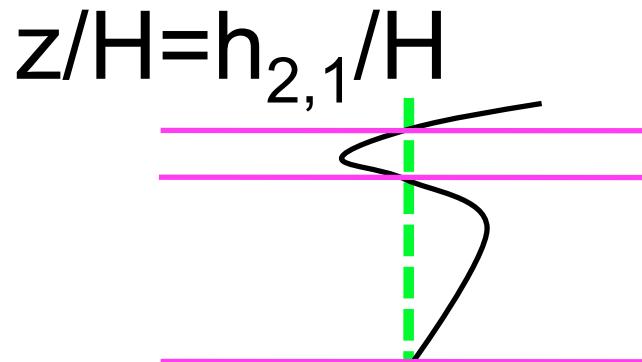
$$z/H = h_{2,1}/H$$



Sigma coordinates????

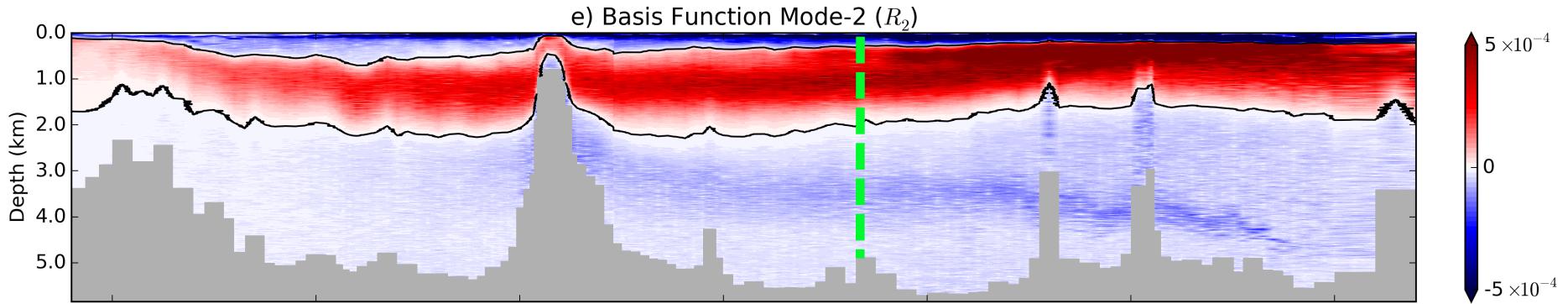


Ensure that there are 3 vertical grid points between zero crossings

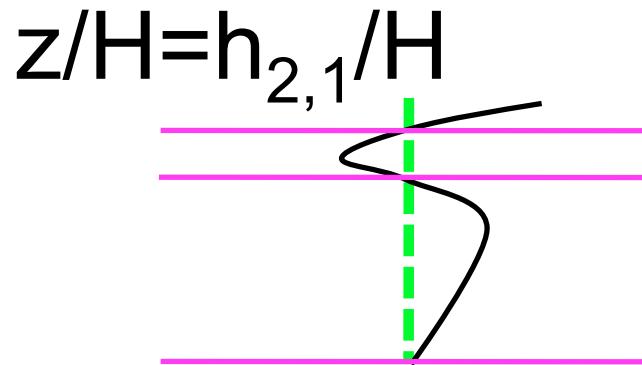


$$\Delta z/H = (h_{2,1})/3H$$

Sigma coordinates????



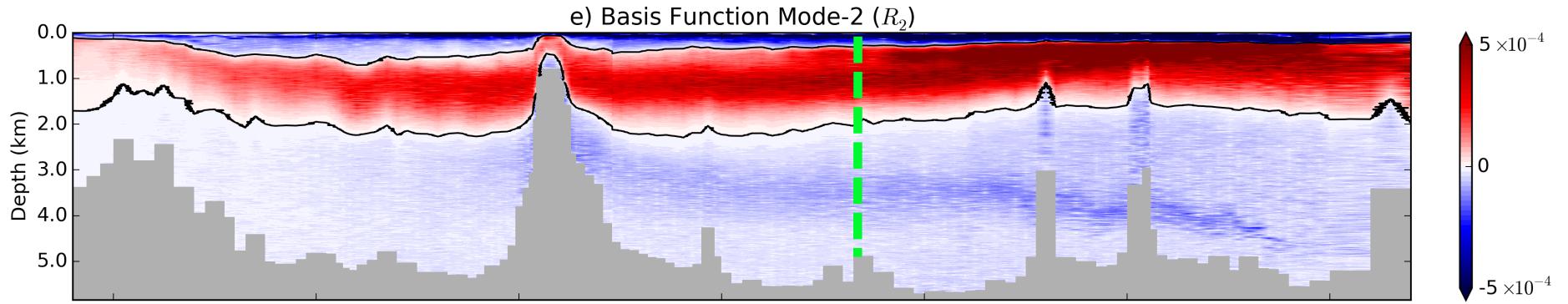
Ensure that
there are 3
vertical grid
points
between zero
crossings



$$\Delta z/H = (h_{2,1})/3H$$

($z/H, \Delta z/H$) pairs for domain of interest

Sigma coordinates????



For mode- m , $\Delta z/H < 1/6m$

Primary purpose of the vertical grid is to resolve horizontal flows

50 z-levels for first mode, 25 levels per additional mode

Minimise subjectivity in ocean modelling

